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# THESIS

**CANINE SUPPLY FOR PHYSICAL SECURITY: AN ANALYSIS OF THE ROYAL AUSTRALIAN AIR FORCE MILITARY WORKING DOG PROGRAM**

by

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March 2016

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The Royal Australian Air Force (RAAF) is undergoing its largest peacetime acquisition of air assets, with increased demand on its physical security elements. Its military working dog (MWD) workforce is required to meet an inventory of 204 by end of year 2023 as a means to provide effective security for RAAF assets. This thesis conducts two areas of research. First, an econometric analysis of MWD gender, breed, and source against select dependent performance variables. Second, a fixed inventory Markov model is developed to determine how many MWDs need to be recruited between 2016 and 2023 to meet the increased quota. My results find that male and vendor-purchased MWDs outperform female and RAAF-bred MWDs, with varying results between German Shepherds and Belgian Malinois. The Markov model transition probabilities validate as sufficiently stationary and determine that 282 canines need to be recruited over the prescribed time period to meet the 204 required by end of year 2023.

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**CANINE SUPPLY FOR PHYSICAL SECURITY: AN ANALYSIS OF THE ROYAL AUSTRALIAN AIR FORCE MILITARY WORKING DOG PROGRAM**

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# ABSTRACT

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ADF | Australian Defence Force |
| ANAO | Australian National Audit Office |
| CBA | Cost Benefit Analysis |
| CTO | Course Terminal Objectives |
| DLOC | Directed Level of Capability |
| DOD | Department of Defense |
| EDD | Explosive Detection Dog |
| EOY | End of Year |
| IED | Improvised Explosive Device |
| HQ 95WG | Headquarters Number 95 Wing |
| MLOC | Minimum Level of Capability |
| MSE | Mean Squared Error |
| MWD | Military Working Dog |
| MWDT | Military Working Dog Team |
| OLOC | Operational Level of Capability |
| OVB | Omitted Variable Bias |
| PTSD | Post-Traumatic Stress Disorder |
| RAAF | Royal Australian Air Force |
| RAAFSFS | Royal Australian Air Force Security and Fire School |
| SASR | Special Air Service Regiment |
| SEAL | Sea, Air and Land |
| U.S. | United States |

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MWD Turk (male German Shepherd), left, and MWD
Faith (female Belgian Malinois), right

Photos courtesy of Australian Defence Force Tracker and War Dog Association

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# I. INTRODUCTION

The Royal Australian Air Force (RAAF) is currently undergoing the largest peacetime acquisition of air assets since its beginnings on March 31, 1921, and is expanding its airborne capabilities to unprecedented breadths, such as unmanned aerial systems and electronic attack, thus maintaining its reputation as the best, small air force in the world (RAAF, n.d.). The expansion of air systems and the increase in the sensitivity of assets requires the RAAF to not only consider capability development and planning for support systems, but also for the combat support elements, to remain sufficiently secure. Accordingly, careful and considered planning of physical security growth and structuring are required to ensure air bases, both expeditionary and permanent, do not become vulnerable to attack or intrusion. My thesis takes a manpower systems perspective of one workforce element within the RAAF's physical security structure: military working dogs (MWDs).

One aspect of my research is to conduct a performance analysis on the RAAF's MWD workforce to determine if any significant dog-specific characteristics warrant consideration in planning for the near future. The characteristics I focus on are gender, breed, and accession source (either from an external vendor or from the RAAF breeding program). Understanding any significant differences in performance between MWDs of differing characteristics will assist in the future planning of which dogs should be acquired, and from what source. In light of the expansion and renewal of the RAAF's air assets, the projected inventory requirement for MWDs is 204 by the end of 2023 (T. Buffett, personal communication, 2015). Accordingly, I expand the scope of my thesis to incorporate a second area of research by developing a fixed inventory Markov model to determine the acquisition requirement for future canines into the RAAF MWD workforce. Together, my research will aid the RAAF in planning not just how and when canines should be acquired to meet the future demands, but also what breed and from which source.

My thesis is broken down into six chapters.

Chapter II outlines the importance of focusing my research on an area such as the RAAF MWD workforce and its significance in the greater scheme of capability development and planning of Australia's air power. I then discuss MWDs in the context of all dogs within society, giving a brief sociological perspective on MWDs. Following this discussion, I outline some of the psychological perspectives in the use of canines in military operations, drawing upon empirical studies conducted in the field of both military and search-and-rescue working dogs, including their relevance to my research. Lastly, I outline the training and assessment structure for RAAF MWDs, including the means by which the dogs progress to their required levels of competency.

In Chapter III, I identify how I compiled data and from what source. I first discuss the data in terms of its strengths and weaknesses for use in my analyses, highlighting any areas of concern in estimating my models and steps taken to address them. The chapter is then divided between the discussion of the data in the context of econometric analysis, followed by discussion in the context of fixed inventory Markov model derivation.

In Chapter IV, I conduct an econometric analysis on select dependent variables representing performance. Specifically, I incorporate quarterly assessment, unit, and operational standard fixed effects to estimate the effects of gender, breed, and source on being assessed as "Competent." I then conduct similar analyses on the three component scores: Basic, Obstacle, and Tactical, to determine the sources of variation in performance. Unsurprisingly, the Tactical component of the quarterly assessment exhibits the greatest variation, as it is the largest portion of the assessment and structured to progressively build upon an MWD's skills in areas such as controlled aggression, Intruder Detection, Man-trailing, and Fire and Movement. Accordingly, I estimate the relationship between the aforementioned explanatory variables on the scores within specific exercises to determine their significance in varying performance. Lastly, I regress the same explanatory variables, with fixed effects, on an MWD's propensity for being placed on a medical waiver. In producing these estimates, my evidence indicates that male, vendor-purchased MWDs are the highest performing. Furthermore, I find that German Shepherds outperform Belgian Malinois in the Man-trailing exercise, but not in

Fire and Movement. Given that German Shepherds have a much higher propensity for requiring a medical waiver, the RAAF needs to consider whether the shortfall in performance in Man-trailing by an MWD workforce that is predominately Belgian Malinois breed is worth the yield in longevity in avoiding medical waivers.

In Chapter V, using the same data set, I derive a fixed inventory Markov model to forecast future canine acquisition out to end of year (EOY) 2023. Using requirements provided by RAAF in meeting the future MWD-specific physical security demands, I develop a transition matrix that identifies the transition rates between and within states, including between arrival, career-performance progression, and retirement. I then validate the transition rates by developing upper- and lower-confidence levels using derived standard errors, to satisfy the Markov principle of sufficient stationarity. Although the data is from 2011–2012, I use the same transition rates in the context of RAAF's MWD workforce balance in 2015 to forecast recruitment requirements out to 2023. My results indicate the RAAF will be required to acquire 282 MWDs between 2016 to EOY 2023, in order to meet the scheduled inventory increase and to account for attrition.

Chapter VI summarizes my results. My findings are that male, vendor-purchased MWDs outperform female MWDs and those sourced from the RAAF breeding program. I find that German Shepherd MWDs outperform Belgian Malinois in Man-trailing exercises, however Belgian Malinois MWDs outperform German Shepherds in Fire and Movement and are significantly less likely to require a medical waiver. My findings will aid the RAAF in deciding the mixture of sex, breed, and source of MWDs in acquiring the 282 canines determined by my fixed inventory Markov model results.

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# II. BACKGROUND

Since the signing of the Joint Strike Fighter development program, the RAAF has begun its largest peacetime acquisition of aircraft in its history. The RAAF is not limiting itself to replacing aging fleets; it is also expanding its airborne capabilities into new territories. The schedule of acquisitions has the RAAF entering a period termed "Next Generation Air Force," which demands capable support elements inclusive of force protection and physical security. MWDs play a critical role in the provision of such security.

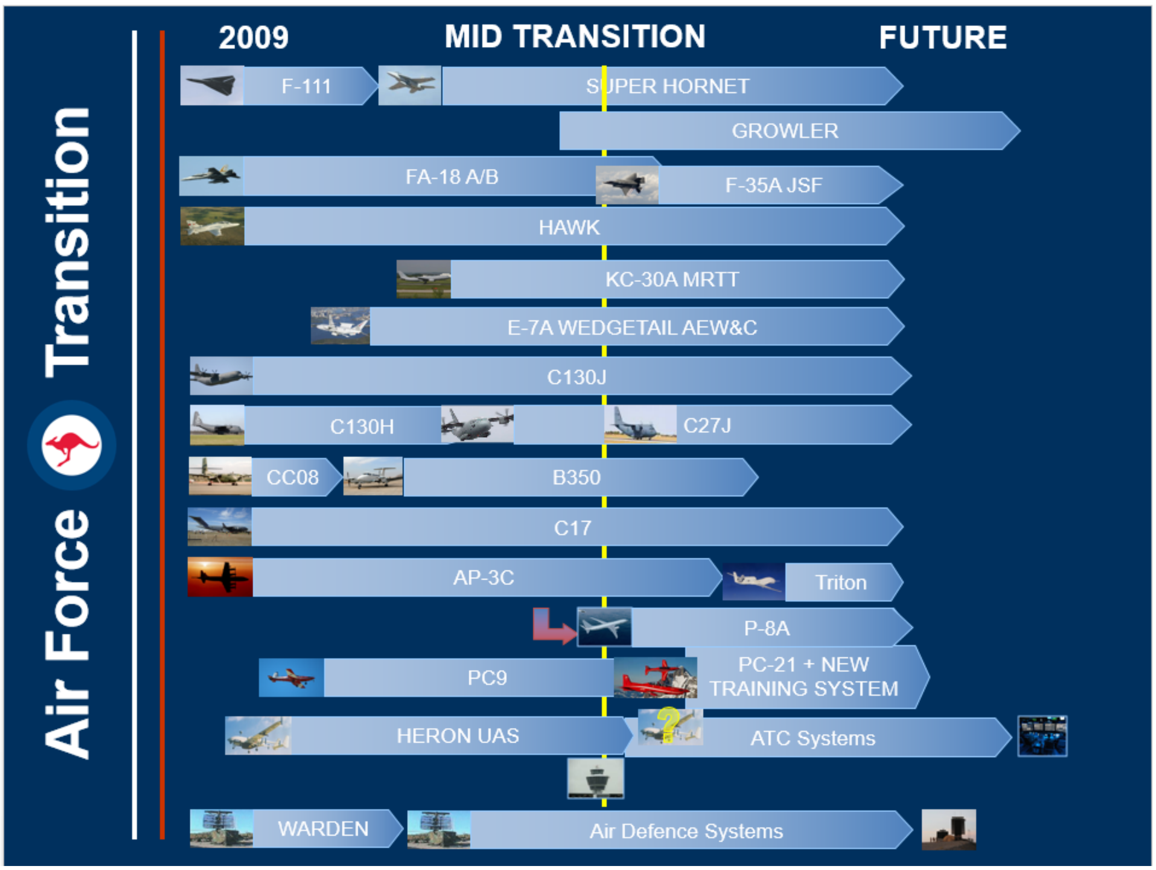
## A. RAAF CAPABILITY AND SECURITY IMPLICATIONS

The RAAFs suite of aircraft systems in 2023 will see an inventory comprising of legacy systems awaiting decommission, their replacement platforms, and the introduction of new airborne capability inclusive of, but not limited to, electronic attack and long-endurance unmanned aerial systems. In 2023, the breadth of airborne capability RAAF will own will be unprecedented in its history. Alongside the 5th Generation F-35A Joint Strike Fighter, the RAAF's inventory of highly sensitive aircraft will include the 4.5 Generation F/A-18F Super Hornet and E/A-18G Growler, E-7A Airborne Early Warning and Control Wedgetail, and the High-Altitude Long-Endurance MQ-4 Triton. The introduction of replacement systems and the new areas of capability are depicted in Figure 1, with 2015 representing the point of mid-transition.

The 2023 transition will subsequently see the RAAF base infrastructure grow and develop to adequately support and sustain its ability to launch and maintain the aircraft, inclusive of operational ground systems. An essential element of this combat support is the provision of physical security to ground infrastructure and the assets, both when deployed and at the air base of origin. Accordingly, RAAF's principle doctrine, *The Air Power Manual,* lists air base protection as a mission of the Force Protection element of enabling Air Power (2013, p. 87). RAAF's *Future Air and Space Operating Concept* (2008, p. 36) prescribes the mission of Force Protection in the context of minimizing the vulnerability of air assets, including its personnel, facilities, and operations. Without

Force Protection, the ability for RAAF to conduct and sustain operations will degrade, owing to a vulnerable foundation. Physical security plays an essential role in the provision of Force Protection, and military working dog teams are an essential element of that capability.

Figure 1. RAAF air asset acquisition timeline




Source: Director General Capability & Planning—Air Force, personal communication, 2015.

The focus of my research is to inform capability planning out to eight years, specifically 2023, when the RAAF's air asset inventory peaks while decommissioning legacy platforms and introducing new systems into service. I conduct this research in two stages: First, I provide an econometric analysis on 24 months of sample RAAF MWD data to ascertain any statistically significant effects of individual MWD independent variables against select dependent performance outcome variables. Second, I develop a

Markov model to determine what, if any, gap in MWD capability might exist in 2023 should the current recruitment, training, and retirement of MWDs continue. However, it is important to first gain an appreciation of MWDs in the context of all dogs in society and how previous research informs my objectives in this thesis.

## B. SOCIOLOGICAL PERSPECTIVES OF MWDS

### 1. Dogs in Society

It is difficult to discuss the sociological perspectives of dogs in military service without first acknowledging the roles that they have in society at large: where they lie, what roles they play, and how we acknowledge them. Generally speaking, dogs fall into one of two categories: companion dogs and service/working dogs.

Companion dogs are the most common role that dogs fill in society, either by providing a relationship for someone living predominantly on their own or by supplementing the relationships within a family unit. Dogs serving in the role of companion have formed their own large piece of the societal puzzle in modern Western culture. In the United States alone, 74.8 million dogs perform the role of companion and cost their owners over $100 billion per year (Udell & Wynne, 2008). Dogs play such a significant role in Western society that, in many cases, the relationships of many dog-owner partnerships is called into question. In particular, dogs have often been considered Earth's greatest manipulators: in exchange for passing themselves off as being adorable, we have provided them a life of luxury, a quality of life beyond that of many other humans elsewhere (Ritland, 2015).

Canines began domestication with humans approximately 15,000 years ago (Inoue-Murayama et al., 2007). The advent of human-dog relationships starts with the simple fact that dogs are animals of association. They associate with humans because we are a source of food and benefits. In turn, humans have welcomed and taken control of relationships with dogs because we are able to exploit our connection with them to gather food and other resources more efficiently (Ritland, 2015). In this respect, we begin to cross the line from viewing dogs as companions and instead as a tool to optimize the achievement of our objectives. The service roles in which we employ dogs are numerous

in society, including search and rescue, hunting and retrieving, drug detection, sled pulling, and as guide dogs for the blind (Udell & Wynne, 2008). One of the more important service roles that dogs perform in our society is the role of the MWD.

### 2. A History of Dogs in Combat

Dogs have been used to aid humans in combat as early as the Stone Age, used offensively by Persians, Greeks, Assyrians, and Babylonians. During the Middle Ages, battle armor and chains were developed just as quickly for dogs as they were for knights' horses (Lemish, 1996). Into the 1600s and 1700s, the British and French used dogs in warfare as tactical decoys, for sentry, and for early warning (Hammerstrom, 2005).

Over the past century, we have seen the role of MWDs develop much more sophisticated capabilities. For example, during World War I, military forces trained MWDs to assist field medics, run messages between lines, perform sentry roles, conduct scouting, transport ammunition, and eradicate rodents (Hammerstrom, 2005). At the start of World War I, German military forces employed 6,000 dogs alone (Lemish, 1996). In World War II, Nazi Germany trained and employed an estimated 50,000 dogs of various breeds for the purposes of carrying light stores, field medic assistance, reconnaissance, and message carrying (Sloane, 1955). The U.S. Marine Corps and Allied forces also employed MWDs during the Korean War and considered them a force multiplier in executing mission objectives (Hammerstrom, 2005).

From Vietnam to Gulf War I and Gulf War II, including Afghanistan, we have seen the employment of MWDs in improvised explosive device (IED) detection, intruder detection, and patrol functions (Hammerstrom, 2005). MWDs are also now widely renowned in film and literature with movies such as *Glory Hounds* and books such as *War Dogs: Tales of Canine Heroism, History, and Love* and *Sergeant Rex: The Unbreakable Bond between a Marine and His Military Working Dog*.

## 3. MWDs: A Capability Perspective

> Superior to any other single type of sensor system, which is after all, precisely what a MWD is: a living, four-footed, mobile sensor capable of detecting people, objects, sounds, and odors with its highly developed senses.
>
> —W. Thornton, *The Role of Military Working Dogs in Low Intensity Conflict*

Notwithstanding that canines have a firm position within our societal history, the question must be asked whether MWDs should be considered expendable equipment with a service life or something else. The United States has a history of disbanding MWDs toward the end of a major conflict, only to find the need for fully trained MWDs in subsequent conflicts (Hammerstrom, 2005; Thornton, 1990).

Is it from a policy perspective, then, that MWDs are considered expendable equipment for which taxpayer dollars are committed, and a capability that must be reviewed routinely for its validity and return on investment? Thornton's 1990 white paper identified the force-multiplier effects of MWDs: their low price and incredible ability to surpass any technological developments and research the United States had underway. Yet, countries such as the United States, Australia, and their allies used MWDs in 2015 to unprecedented lengths and competence not seen since the Vietnam War. Against the backdrop of incredible advancements of engineering and technology over the past 25 years, it was an MWD as part of SEAL Team 6 that was used to enter Osama bin Laden's compound in Abbottabad, Pakistan, in 2011 and not some sophisticated piece of machinery (Forer, 2011).

From a battlefield perspective, it is particularly evident that we consider MWDs vital in delivering a valuable level of capability. In particular, the use of MWDs for physical security and IED detection has become particularly prominent during their service in Iraq and Afghanistan, since 2003. So capable are MWDs in the detection of IEDs that the latest, ultrasonic detection devices only sense IEDs with around 50% accuracy, while MWDs have been found to achieve 80% success (Milner, 2013). Further, scientific research by Myers and Furton (2001) concludes that while instrument methods

have some advantages “detector dogs still represent the fastest, most versatile, reliable real-time explosive detection device available” (p. 487). Accordingly, until technology can match the MWD in affordability and sensory ability—an ability so high that they can detect a single teaspoon of sugar in one million gallons of water through smell (Ritland, 2015)—MWDs will likely remain firmly lodged into a modern military’s arsenal.

### 4. Veteran MWDs

MWDs returning from warlike service are attracting greater awareness within Western societies since coalition operations in Iraq and Afghanistan in 2003. Until recently, MWDs would reach the end of their service and be euthanized without consideration for post-service care. However, the acknowledgment of the prominence of canines in modern Western society has meant that MWDs returning from warlike service receive greater care. As an example, charity groups in the United States raise funds for the rehoming of MWDs returning from combat, to spare them from euthanasia and instead place them into adoption (Hickman, 2013). In addition, the U.S. Congress has also authorized a privately funded venture to provide lifetime care for MWDs should adoption not be viable (Blansett, 2014). The Royal Australian Air Force has also adopted a similar policy for retiring MWDs, not just limited to those returning from warlike service, enabling them to retire to the handler’s home to live out the rest of their natural life (Wilson, 2013).

Similar to returning human veterans, Australia and greater Western society have witnessed a rise in memorials and use of honors and awards dedicated to slain and returned veteran MWDs. Examples include the Australian Defence Force Tracker and War Dog Association and the Royal Society for the Prevention of Cruelty to Animals (RSPCA), which have established independent honors and awards to that of the Australian Defence Organisation’s Defence Honours and Awards system. Both organizations have issued awards such as the War Dog Operational Medal and Purple Cross (RSPCA) for acts of bravery. One such recipient of both awards was Sarbi, a Labrador–Newfoundland who—during a fire fight in Oruzgan Province in Afghanistan in which nine Australian soldiers were wounded and another, Corporal Mark Donaldson

was awarded the Victoria Cross—went missing for 13 months and found her way back into Australian hands (Hatch, 2015).

In light of the new position MWDs hold in society, the question remains whether governments such as Australia will one day incorporate canines into their honors and awards systems. Both historically and in modern battlefields, the relationship between MWDs and their handlers have been instrumental in delivering operational effectiveness. Accordingly, it is important that we consider the psychological and behavioral aspects of canines that inform their selection and performance as MWDs.

## C. PSYCHOLOGICAL PERSPECTIVES OF MWDS

### 1. The Relevance of MWD Psychology

Significant research in canine psychology and behavioral science has been conducted to improve the employability of MWDs among our ranks. Canines are living, breathing, carnivorous mammals that in the wild and prior to domestication would hunt for their prey in packs. It is their behavioral characteristics that indicate the effectiveness of the individual canine in its ability to hunt, communicate, and interact with its peers. Earlier studies, such as that of renowned psychologist Ivan Pavlov, analyzed the behavioral traits of canines and their ability to learn and associate as part of classical conditioning experiments, training dogs to salivate upon hearing an external stimulus (McLeod, 2007). Therefore, the behavioral characteristics of canine candidates for consideration in MWD roles are vital to their success in the combative nature of their potential tasks.

Behavioral characteristics assessed in canine subjects considered for training as MWDs and other roles in society have become a very large field of psychological study. For MWD training in particular, aspects such as confidence, curiosity, and stamina are built into assessments to determine and develop suitability for service in the field. The MWD training programs measure the behaviors, collectively analyzing the results and inferring individual propensity for successfully completing further training (Gosling, Hilliard, & Sinn, 2010). Behavioral scientists also analyze the various breeds of canines

to determine genetic predispositions to different behaviors, very similar to that of humans (Inoue-Murayama et al., 2007).

Gosling et al. (2010) concisely outline how candidate canines are scored in as part of their MWD training at 341st Training Squadron, Lackland Air Force Base, Texas. These tests include environmental sureness, static object interest, thrown object interest, possession (maintained interest in a toy), physical possession (wrestling with handler upon attempting to retake a toy), search activity, search stamina, defense, threat aggression, bite quality, attention transfer (from target to bite sleeve), and gun sureness. Owing to the vast array of the behavioral tests just described, militaries such as the Australian Defence Force (ADF) and the U.S. Department of Defense (DOD) choose particular breeds with certain predispositions to run an efficient training and output program for delivering MWDs to the field (Inoue-Murayama et al., 2007). Accordingly, militaries such as the U.S. DOD typically restrict themselves to German Shepherds, Belgian Malinois, and Dutch Shepherds (Gosling et al., 2010). By comparison, the RAAF restricts its breeds to German Shepherds and Belgian Malinois for the same purposes and, similar to the U.S. DOD, Labrador Retrievers for IED detection (Wilson, 2015). However, the research by Gosling et al. (2010) provides fundamental insight for my research as both the RAAF and U.S. DOD MWDs undertake similar initial selection, training, and duties.

Gosling et al. (2010) take a quantitative approach to the behavioral tests administered as part of the studies to determine whether behavioral and personality tests early in an MWD candidate’s life are predictive of future success in qualifying its patrol and detection competency requirements. While their results highlight a need for greater test-retest reliability in recording consistent evaluations, the study also identifies the importance in acknowledging the psychology of MWDs in order to optimize selection and training output.

Whereas Gosling et al. (2010) focus their research on the predictive validity for future testing, my research is focused on identifying whether statistically significant and meaningful relationships exist between dog characteristics and indicators of performance.

### 2. Post-Traumatic Stress Disorder

For centuries, soldiers, sailors, and airmen have succumbed to various forms of what modern society now refers to as post-traumatic stress disorder (PTSD). Namely, following some traumatic incident, PTSD is the inability to overcome the reality of what occurred, manifesting itself in delayed stress reactions experienced by the observer (National Center for PTSD, 2013). Considering the individual personality traits and behavioral characteristics inherent in canines, it is not surprising that MWDs are also diagnosed with PTSD, similar to their human counterparts. Studying the PTSD symptoms in MWDs returning from combat service began several years ago (Dao, 2011). A film documentary, *Glory Hounds*, depicts the PTSD symptoms in returned MWDs. In the film, a specific IED survivor who fostered his MWD refers to the nightmares, heavy breathing, and anxiety that the canine has experienced since returning from service (Manning, 2013).

Worldwide, militaries are increasingly observing and treating PTSD in returned MWDs. For example, the RAAF's attendance at the 2015 International Working Dog Conference highlighted that military services such as the U.S. DOD, Israeli Defense Forces, and German Armed Forces have installed CCTV cameras to monitor the behaviors, symptoms, and stimuli of returned MWDs exhibiting PTSD (T. Buffett, personal communication, 2015). With over 5% of all MWDs returned from Afghanistan and Iraq being diagnosed with PTSD, the rise in concern and effort is not unjustified when considering the behaviors that canine psychologists are highlighting, such as cowardice or aggravation at gunfire, unwillingness to enter buildings, and random bouts of aggravation or dependence on their handlers (Dao, 2011). The effects of PTSD, much as in human sufferers, are detrimental to employing MWDs in further operational roles, particularly for those who must pass environmental factors such as gun sureness (Gosling et al., 2010).

One must ask: Given the history of relationships between humans and canines, would it be useful for human sufferers of PTSD to be matched with canine sufferers? With policies surrounding the rehoming and retirement of MWDs following service, are we likely to see an advent of charity-sponsored programs, similar to the retirement and

veterinarian care programs supported by Congress, focused on rehabilitation of MWDs? Treatments used to curb the symptoms of PTSD in MWDs have included light exercise and removal from operational patrols for lighter severities, replicating similar techniques used to treat human sufferers. The use of positive association and reinforcement for cases with worse symptoms have also been employed, but the future of PTSD treatment in MWDs remains to be seen (Dao, 2011).

While my focus does not consider the effects of PTSD, it is relevant to consider how the incidence of PTSD could affect the data. During data compilation, some MWDs were not available for their quarterly assessment, as they were on operational deployment. Future quantitative studies using RAAF MWD data may wish to consider capturing the deployment history of individual MWDs to assess whether there are any statistically significant performance effects from returned MWD, both deployed in general and by specific operation. Undiagnosed PTSD in RAAF MWDs within the sample data set would present as a source of omitted variable bias within the results; however, considering that none were deployed to combat zones during the sample period, it is unlikely this source of bias exists.

### 3. The MWD–Handler Relationship

For any military recruit entering service, a period of "boot camp"-style training is undertaken to forge teamwork and relationships with colleagues. Similarly, upon entering any new unit, teams are formed and relationships built, and it is the health of these relationships that determine operational effectiveness in the field. This group psychology also applies in human-canine interactions, specifically when an MWD is paired with a handler to form a military working dog team (MWDT). Considering the nature of many of the roles involving MWDs, including IED, drugs, weapons cache, and human detection, the criticality of the relationship should not be underestimated (Wilson, 2015).

We cannot refute that the presence of behavioral traits in MWDs are evidence of a personality incumbent within an individual canine. This is particularly apparent considering the practice that military services such as the RAAF adopt, where MWD candidates are matched with potential handlers, to ensure the personalities are

complementary (Wilson, 2015). The importance of the match is not unprecedented, with the quote from Robert Kollar highlighting the critical role the relationship between handler and MWD plays in operational effectiveness: “if the guy on the other end of the leash doesn’t understand the dog, cannot pick up the subtle alert, then someone is going to get killed” (Hammerstrom, 2005, p. 28). Ex-Navy SEAL and dog breeder/trainer Mike Ritland details respect, loyalty, and trust as the primary contributors to successful MWD-handler relationships, similar to the dynamics between human elements within military units (2015). The research by Lefebvre, Diederich, Delcourt, and Giffroy (2006) empirically demonstrates the significance of the relationship, where the study of Belgian Army MWDs focuses on the effects of greater bonding between handlers and their assigned canines. Of the sample of MWDs and handlers observed, those who interacted with their canines outside of hours and/or took them home between shifts experienced greater levels of obedience than those who did not. Specifically, the handlers who invested more time were less likely to repeat their commands during testing and experienced fewer instances of biting.

We should not discard the psychology of the relationship dynamics between MWDs and their handlers, but instead view them with closer scrutiny. No avenues exist between canine and human for mediation in the workplace when the relationship either breaks down or where trust is lost, as would be the case between humans. It is the success of the partnership between an MWD and its handler that ensures optimal performance in difficult situations, such as IED detection in clearing paths for patrolling humans.

The significance of the MWD-handler relationship poses as a potential source of measurement error, as the focus of my research does not include handler data. Fortunately, the assignment of MWDs to handlers within the sample is random, which likely mitigates any potential bias. Where this would prove detrimental to the results of my research, would be if there was some unit-specific trend for either developing relationships between handlers and MWDs at higher levels than the other units within the data set, or similarly if one unit had poorer relationships. However, the likelihood of this occurring is significantly low, considering both the random assignments of staff, instructors and MWDTs to units and that MWDs and handlers are paired at RAAF

Security and Fire School (RAAFSFS), RAAF Base Amberley, Queensland prior to proceeding to their operational units from where the data is drawn.

## D. RAAF MWDS

### 1. RAAF MWDs and Explosive Detection Dogs

The RAAF terminology of MWDs includes explosive detection dogs (EDD), however my research excludes EDDs. EDDs have a focused capability, and do not encompass competencies such as obstacle negotiation, intruder detection, attack, and fire and movement in the provision of physical security. RAAF MWDs are currently used and will continue to be used for providing physical security of air bases and assets, whether in domestic or deployed environments (T. Buffett, personal communication, 2015).

### 2. RAAF MWD Accession Source and Breed

RAAF MWDs are sourced either internally from its own breeding program or externally through vendor purchase. The strategic intent for the breeding program managed by the RAAF is to supplement the majority of MWDs purchased from external vendors. However, this accession source structure has reversed and the RAAF is now in a position where its breeding program is robust and effective enough to act as a primary accession source for MWDs (T. Buffett, personal communication, 2015). The results from my econometric analyses controls for the effects of breeding program MWDs against those sourced from an external vendor, as well as for canine gender. These results are invaluable for RAAF capability planning, as any future study conducted on the fiscal viability of either disbanding or developing the breeding program will aid in determining which accession source to focus efforts on and what gender may or may not yield higher performance returns.

The RAAF uses Belgian Malinois and German Shepherd canines for training as MWDs. Both breeds are bred internally through the RAAF breeding program as well as purchased through external vendors (T. Buffett, personal communication, 2015). Both breeds are common among MWDs worldwide, including the Belgian Army and U.S. DOD, as used in empirical studies by Gosling et al. (2010) and Lefebvre et al. (2006).

## 3. Initial Assessment

Canine subjects produced by the RAAF breeding program are raised within a RAAF controlled environment as newborn puppies until they are at a sufficient age to be considered for the foster care program. The foster care program ensures puppies are given to either approved caretakers, Security Force units within Number 95 Wing, RAAF, or to the Special Air Service Regiment (SASR), Australian Regular Army, to develop and later return to RAAFSFS, RAAF base Amberley, Queensland (T. Buffett, personal communication, 2015).

Canines returning from the foster care program are approximately seven months of age and are immediately assessed for their environmental soundness and suitability for further development. Environmental soundness encapsulates the working environment of RAAF Physical Security units, where MWDs will live out the majority, if not the remainder, of their natural lives. Specifically, the assessors seek to mitigate the risk of self-harm, fear biting, or cowering and aggression toward handlers. This working environment is not limited to just the kennels within established bases, but includes the broader facets of MWD life, including deployed environments and the ability to be transported by road or air (T. Buffett, personal communication, 2015).

Suitability for development as an MWD involves focusing on how outgoing the individual personality is and its boldness and confidence in adverse and hostile situations. Basic characteristics such as retrieval, prey drive, and controlled aggression are assessed, including bite quality. The tests include confidence in the face of small arms fire (using blank ammunition) or the cracking of a whip, basic retrieval, boldness when presented with new environments or obstacles, and aggression and willingness to bite a hessian bag or an aggressor’s padded arm (T. Buffett, personal communication, 2015).

The environmental soundness and suitability assessments are also conducted for vendor canines prior to purchase. However, unlike RAAF-bred puppies that return to RAAFSFS at approximately seven months of age, vendor purchased canines are typically recruited as adults aged between two and three years. Following acquisition, the vendor

canines are then evaluated against the same criteria as canines returning from the foster care program (T. Buffett, personal communication, 2015).

### 4. RAAFSFS

Whether sourced from an external vendor or bred internally, RAAF MWDs begin their effective service at the RAAFSFS, where they are paired with a handler to begin basic training. The pairing of MWDs with their handlers is determined through observed personalities of both the handler and the MWD. The MWD training is conducted over a 10-week period with a curriculum focused on obedience, obstacle negotiation, and tactics.

The following information pertaining to Basic, Obstacle, and Tactical component exercises was sourced from Squadron Leader Tony Buffett via personal communication (2015).

In order to meet the Obedience requirements of the RAAFSFS MWD course, the MWD must be able to complete the following exercises unleashed:

1. **Heel.** The MWD is required to conduct about turns, both left and right, and halt with the handler, maintaining the correct position by the handler's side at all times.

2. **Sit.** Upon halt of movement by the handler, the MWD immediately sits at the handler's side without additional commands.

3. **Stay.** The handler commands the MWD to sit and moves out of the dog's sight, where they continue to observe the dog and it remain in position for an indefinite period.

4. **Distance Control.** With the MWD in the stay position, the handler moves to within sight of the MWD and commands it to adopt the down from the sit position and vice versa. The handler then commands it to stay and moves out of sight without the MWD breaking position.

5. **Recall.** Upon command by the handler, the MWD immediately returns to the handler's side.

In order to meet the Obstacle requirements of the RAAFSFS MWD course, the MWD must be able to negotiate the following exercises unleashed:

1. **Hurdle.** Leap over a 1-m-high hurdle.

2. **Plank Walk.** Walk 3 m along a raised plank.

3. **Tunnel.** Traverse a tunnel between 2 m and 4 m long, with an orifice of 380 x 380 mm.

4. **Stairs.** Traverse 3 m of steps, leading to a platform raised 2 m above the ground, followed by 3 m of downward steps.

5. **Fire Hoop.** The MWD is sufficiently confident to jump through a hoop that is completely ablaze.

In order to meet the Tactical requirements of the RAAFSFS MWD course, the MWD must be able to negotiate the following exercises unleashed:

1. **Intruder Detection.** The MWD is patrolling a search area and uses olfaction to detect the scent of hidden intruders. An intruder breaks position and retreats to an alternative point no more than 100 m away, out of view of the MWD. Upon being brought to the original position of the intruder, the MWD uses olfaction to locate the intruder's new position to attack and capture them.

2. **Search and Protection.** While focusing on protecting the handler, the MWD must consider any potential intruders that may pose a threat to the handler and recognize an aggressive movement as a command to attack. Only upon order by the handler to cease does the dog halt and adopt the sit or down position, watching the intruder. Any further movement by the intruder is a command to attack.

3. **Man-trailing.** A trail-layer will drop an object and relocate 100 m away in a straight line, in any direction and out of view of the MWDT. The MWD is required to locate the object and then use ground scent to locate and capture the trail-layer.

4. **Building Search.** Upon being introduced to a building, the MWD reacts positively to the command to search, and turns left through every doorway and in searching every room (for ease of the handler, who is always to the MWD's right). The MWD must maintain focus and motivation to search through the building until it discovers the human out of a variety of hidden locations within the building.

5. **Cease Attack.** An MWD is commanded to attack and capture an intruder. When the intruder halts, and upon command by the handler to cease attack, the MWD immediately stops and adopts either the "sit'" or "down" position until either the intruder moves or the handler comes to the MWD's side.

The aforementioned Basic obedience, Obstacle, and Tactical elements comprise the course terminal objectives (CTO) for graduating RAAFSFS and subsequently being allocated to a Physical Security unit to begin effective service. The CTO standards are then reassessed upon arrival at the allocated unit, to determine areas required for any potential further training and to determine the MWDT's need for additional training.

### 5. Minimum and Operational Levels of Capability

The ADF Performance Management System measures its capabilities by first determining what the Directed Level of Capability (DLOC) is, in order for a force element to be employed effectively as part of a wider, consolidated force. The Operational Level of Capability (OLOC) is a measurement that identifies specific capability deliverables under DLOC. The Minimum Level of Capability (MLOC) is "a level of capability that a force element is objectively required to have, in order for it to be able to progress to OLOC within the Readiness Notice period" (Australian National Audit Office [ANAO], 2003, p. 30).

Upon arrival at a Physical Security unit, and successfully retesting against the CTO criteria, MWDs are considered to be at MLOC and begin assessment against a progressive competency structure with the goal of reaching OLOC status. As a means to be considered at either MLOC or OLOC, MWDs are assessed against five performance standards known as "Operational Standards." MWDs at Operational Standards 1 through 3 are at MLOC, and Operational Standards 4 and 5 at OLOC. The section that follows outlines the means by which MWDs progress through these Operational Standards (T. Buffett, personal communication, 2015).

### 6. Operational Standards

MWDs progress from MLOC to OLOC through the use of quarterly assessments, and are assessed as "Competent" or "Not Yet Competent" against their respective Operational Standard.

Table 1. Operational Standard performance requirements

| **Operational Standard** | **Basic** | **Obstacles** | **Tactical** |
|---|---|---|---|
| One | 70% | 70% | 80% |
| Two | 70% | 70% | 80% |
| Three | 80% | 80% | 80% |
| Four | 80% | 80% | 80% |
| Five | 80% | 80% | 80% |

Adapted from: T. Buffett, personal communication, 2015

### ***a. Operational Standard 1***

Operational Standard 1 is the first performance standard against which MWDs are assessed, following completion of training at RAAFSFS and upon arrival at a Physical Security unit.

The information pertaining to Operational Standards and their assessments was obtained by Squadron Leader Commander Tony Buffett through personal communication (2015).

The following exercises represent the Basic requirements needed for competency at this standard:

1. **Heel.** The MWD is required to maintain a position no more than 20 cm from the handler's left leg during travel and sitting parallel to the handler upon halting, without command. Points are deducted for additional commands, or not maintaining the correct position at the handler's side. MWDs are given an immediate zero should they run away from the handler.

2. **Distance Control.** With the MWD in the stay and down position, the handler moves 1 m from the dog and commands it to adopt the sit from the down position and vice versa. Points are deducted for breaking position or requiring physical assistance by the handler.

3. **Recall.** Upon command by the handler, the MWD immediately returns to the handler's side from a distance of 20 m. Points are deducted if the MWD returns at either a walking pace and/or adopts the incorrect position once recalled.

4. **Stay.** The MWD must maintain the down and sit positions for 2 minutes, without distractions and with handler in sight.

An MWD must successfully negotiate the following Obstacles one at a time, unleashed, to meet Operational Standard 1. Points are deducted for any additional commands required by the handler.

1. **Hurdle.** Leap over a 1-m-high hurdle .
2. **Window.** Leap through an open window with a 600 mm aperture, the center of which is 1070 mm above the ground.
3. **Plank Walk.** Walk 3 m along a raised plank.
4. **Tunnel.** Traverse a tunnel between 2 m and 4 m long, with an orifice of 380 x 380 mm.
5. **Stairs.** Traverse 3 m of steps to a platform raised 2 m above the ground, followed by identical downward steps.
6. **Fire Hoop.** The MWD is sufficiently confident to jump through a hoop that is completely ablaze.

The following Tactical exercises must be completed to the prescribed standards, unleashed (unless otherwise detailed) in order to meet Operational Standard 1.

1. **Intruder Detection.** The MWD is patrolling in a search area and uses olfaction to detect the scent of hidden intruders. An intruder is hidden within a defined patrol area and, once the intruder is detected, the distance between the MWD and the intruder is measured. The MWD is awarded full points for detecting at a distance of 100 m or more, with points deducted at 20-m intervals shorter than the standard. A score of zero is awarded where the MWD fails to detect at more than 10 m.
2. **Cease Attack—known to the handler.** Following detection of the intruder in the preceding exercise, the intruder is to break from position and the MWD is commanded to attack and capture them. When the intruder halts, and upon command by the handler to cease attack, the MWD immediately stops and adopts either the “sit” or “down” position until either the intruder moves or the handler comes to the MWD’s side. The MWD must cease and adopt the correct stay-watch position within 1–10 m of the intruder in order to successfully complete the exercise. Zero points are awarded if the MWD does not maintain the stay-watch position following ceasing the attack or if it makes contact with the arm sleeve of the intruder before doing so. The MWD must score full points in this exercise.

3. **Cease Attack—unknown to the handler.** As per the requirements of "Cease Attack—known to the handler", however incorporated into another exercise or scenario deemed appropriate by the assessor and unbeknownst to the handler. The MWD must score full points in this exercise.

4. **Search and Protection.** Following a Cease Attack exercise, the handler simulates a physical inspection of the intruder while the MWD maintains the stay-watch position. During inspection, the intruder attacks the handler and the MWD is required to attack without command. Only upon order by the handler to cease does the dog halt and adopt the sit or down position, watching the intruder. Any further movement by the intruder is a command to attack. Points are deducted when the MWD breaks position or watch, and a zero is awarded if it attacks prior to the intruder moving.

5. **Man-trailing.** Leashed, the MWD is to pursue a 500-m trail laid up to 30 minutes in advance, with the first of 3 articles laid not less than 200 meters from the starting point. Prior to pursuing the trail, the MWD is presented with a host article to aid the detection of the trail-laid articles.

6. **Building Search.** Upon being introduced to a building, the leashed MWD reacts positively to the command to search, turns left through every doorway and searches every room (for ease of the handler, who is always to the MWD's right). The MWD must maintain focus and motivation to search through the building until the human is detected and found. Upon finding the target, the MWDT must complete searching the remainder of the building. Incorrectly indicating a target location results in a loss of points on each occasion.

7. **Control under Gunfire (Operational Standards 1 and 2, only).** Using blank ammunition, an exchange of fire between the handler and an enemy 100 m away occurs during a simulated patrol. During the exchange, the MWD is assessed in their confidence and soundness with gunfire. The MWD is awarded zero points where it exhibits avoidance during the gunfire.

***b. Operational Standard 2***

After being assessed as "Competent" at Operational Standard 1, the MWDT progresses to Operational Standard 2. The following Basic exercises and standards represent the requirements in order to consider an MWD competent:

1. **Heel.** As per Operational Standard 1.

2. **Distance Control.** As per Operational Standard 1, however conducted at a distance of 2 m.

3. **Recall.** As per Operational Standard 1, however conducted at a distance of 25 m.

4. **Stay.** The MWD must maintain the down and sit positions for 1 minute, with distractions and handler in sight. Distractions can include blank ammunition fire and attack sleeves placed in visual sight of the MWD.

The following Obstacles must be successfully negotiated one at a time, unleashed, to meet Operational Standard 2. Points are deducted for any additional commands required by the handler.

1. **Hurdle.** As per Operational Standard 1.

2. **Window.** As per Operational Standard 1.

3. **Plank Walk.** As per Operational Standard 1.

4. **Tunnel.** As per Operational Standard 1.

5. **Stairs.** As per Operational Standard 1.

6. **Fire Hoop.** As per Operational Standard 1.

The following Tactical exercises must be completed to the prescribed standards, unleashed (unless otherwise detailed) in order to meet Operational Standard 2.

1. **Intruder Detection.** As per Operational Standard 1.

2. **Cease Attack—known to the handler.** As per Operational Standard 1.

3. **Cease Attack—unknown to the handler.** As per Operational Standard 1.

4. **Search and Protection.** As per Operational Standard 1.

5. **Man-trailing**. As per Operational Standard 1, however with the first of the 3 articles laid not less than 300 m from the starting point.

6. **Building Search.** As per Operational Standard 1.

7. **Control under Gunfire (Operational Standards 1 and 2, only).** As per Operational Standard 1, however must score full points in this exercise.

***c. Operational Standard 3***

Operational Standard 3 is the last MLOC standard, prior to proceeding to OLOC in Operational Standard 4. The following Basic exercises and standards represent the requirements in order for an MWD to be considered competent:

1. **Heel.** As per Operational Standard 2.

2. **Distance Control.** As per Operational Standard 2, however conducted at a distance of 5 m.

3. **Recall.** As per Operational Standard 2.

4. **Stay.** The MWD must maintain the down and sit positions for 2 minutes, with distractions and handler out of sight.

An MWD must successfully negotiate the following Obstacles one at a time, unleashed, to meet Operational Standard 3. Points are deducted for any additional commands required by the handler.

1. **Hurdle.** As per Operational Standard 2.

2. **Window.** As per Operational Standard 2.

3. **Plank Walk.** As per Operational Standard 2.

4. **Tunnel.** As per Operational Standard 2.

5. **Stairs.** As per Operational Standard 2.

6. **Fire Hoop.** As per Operational Standard 2.

The following Tactical exercises must be completed to the prescribed standards, unleashed (unless otherwise detailed) in order to meet Operational Standard 3.

1. **Intruder Detection.** As per Operational Standard 2, however to a distance between 100–150 m.

2. **Cease Attack—known to the handler.** As per Operational Standard 2.

3. **Cease Attack—unknown to the handler.** As per Operational Standard 2.

4. **Search and Protection.** As per Operational Standard 2.

5. **Man-trailing**. As per Operational Standard 2.

6. **Building Search.** As per Operational Standard 2, however with high, low, and head-height searches incorporated into the exercise.

7. **Urban Detection.** This exercise is introduced at Operational Standard 3, owing to its advanced nature. While on a simulated patrol in an urban environment such as a flight line, in either day or night, an intruder appears and then proceeds to a hiding spot no more than 300 m away. The MWD must lead the handler to the point of first appearance and locate the intruder within 10 minutes.

8. **Fire and Movement.** In a simulated patrol scenario, an MWDT is accompanied by a Section Commander and an enemy person is concealed no less than 150 m away. Throughout the scenario, the MWD is required to adopt the down position upon command and without tension being applied to the leash. Using blank ammunition, the enemy opens fire and the MWDT is required to go to ground while commanding the MWD to down and stay. In concert with instruction from the Section Commander, the MWDT advances four bounds while exchanging gunfire. The MWD is assessed on both its soundness with gunfire and obedience during the gunfire exchanges. If the MWD exhibits severe avoidance to gunfire, it is awarded zero points for the exercise. Points are also deducted for each occasion the MWD demonstrates aggression toward the handler's weapon while firing, and where tension on the leash was used to prompt it to adopt the down-stay position. The MWD must score at least 80% in this exercise to be deemed competent.

9. **Test of Courage.** This exercise requires the MWD to attack an evading intruder who subsequently turns and runs toward the MWD in an aggressive manner, making threatening gestures with a stick. During capture by the MWD, the intruder continues to act aggressively and the MWD required to maintain the capture. Zero points are awarded if the MWD does not engage and attack the intruder.

***d. Operational Standard 4***

Operational Standard 4 is the first standard at OLOC. The following Basic exercises and standards represent the requirements in order for an MWD to be considered competent at this standard:

1. **Heel.** As per Operational Standard 3.
2. **Distance Control.** As per Operational Standard 3.
3. **Recall.** As per Operational Standard 3.
4. **Stay.** As per Operational Standard 3.

An MWD must successfully negotiate the following Obstacles one at a time, unleashed, to meet Operational Standard 4. Points are deducted for any additional commands required by the handler.

1. **Hurdle.** As per Operational Standard 3.
2. **Window.** As per Operational Standard 3.
3. **Plank Walk.** As per Operational Standard 3.

4. **Tunnel.** As per Operational Standard 3.

5. **Stairs.** As per Operational Standard 3.

6. **Fire Hoop.** As per Operational Standard 3.

The following Tactical exercises must be completed to the prescribed standards, unleashed (unless otherwise detailed), in order to meet Operational Standard 4:

1. **Intruder Detection.** As per Operational Standard 3, however to a distance between 160–200 m.

2. **Cease Attack—known to the handler.** As per Operational Standard 3.

3. **Cease Attack—unknown to the handler.** As per Operational Standard 3.

4. **Search and Protection.** As per Operational Standard 3.

5. **Man-trailing**. As per Operational Standard 3, however with the trail extended to between 500–1000 m and the articles placed no closer than 200 m of each other.

6. **Building Search.** As per Operational Standard 3, however conducted with or without a leash.

7. **Urban Detection.** As per Operational Standard 3.

8. **Fire and Movement.** As per Operational Standard 3.

9. **Test of Courage.** As per Operational Standard 3.

***e. Operational Standard 5***

Operational Standard 5 is the highest standard a RAAF MWD can obtain, while at OLOC. It requires the MWD to meet all the required standards at Operational Standard 4, however with the only exception being the modification of the Man-trailing exercise within the Tactical component of the assessment. The standard remains as per Operational Standard 4 however with the trail extended to between 800–1000 m and laid 30 minutes prior to the start of the exercise. Further, the MWD must be able to identify the age of the track as being less than or older than 12 hours and indicate the direction of the target by scent.

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# III. DATA

## A. SAMPLE DESCRIPTION

The sample data for this research was sourced from Headquarters Number 95 Wing (HQ 95WG), Combat Support Group, RAAF Base Amberley, Australia. Every Physical Security unit within RAAF that employs MWDTs is responsible to provide HQ 95WG with electronic copies of quarterly assessment reports. There, copies of all quarterly assessments are kept in a single electronic repository as a source for any future use in capability reviews or data analyses.

The data was manually transcribed for each MWD across four out of a possible eight units, for each quarterly assessment from beginning 2011 through to EOY 2012, totaling eight quarters. The units were selected using the random number generator in Microsoft Excel (Excel) as a means to mitigate any potential biases resident in the selection of units (for example, selecting only those units responsible for providing physical security for air combat assets might see stricter grading against certain exercises than others). Despite the labor-intensive task of manually transcribing the data from PDF and Microsoft Word documents into an Excel spreadsheet, this method enables me to introduce both MWD and quarter-specific controls. Further, having collected the data over an eight-quarter observation period, resulting in a panel data format to conduct my research.

Across the four units there are a total of 110 MWDs, whose assessments are recorded over the eight quarters, producing a total of 880 observations. Each MWD was assessed quarterly, with the individual MWD's service status ("Pre-service," "Active," "Pre-retirement," and "Retired"), unit, medical-waiver status, and Operational Standard identified. Additionally, dummy variables are included to identify whether the MWD was unavailable for testing, if it was assigned to pool MWD duties, or if it was retested to achieve the recorded results. I compiled 32 variables per quarter, per MWD, totaling 28,160 data points, not including the MWD-specific information that remained constant throughout the data set. The MWD constants are: serial number, breed, gender, birth date,

teamed date, retirement date, and source (external vendor or RAAF MWD breeding program).

Using the Operational Standards outlined in Chapter II and the scores for each of the exercises, I created the necessary script in Stata to generate a dummy variable that calculated the assigned scores, taking into consideration any medical waivers, and identified the MWD as “Competent” or “Not Yet Competent” at their Operational Standard. Notwithstanding, this may present as a source of measurement error in any econometric estimation, as discretionary decisions made by the assessors in assigning “Competent” or “Not Yet Competent” ratings might be at odds with the grading structure. However, any measurement error will likely be negligible and not sway the parameter estimates.

An inconsistency that lies resident within the data set, owing to the release of an authoritative publication in early 2012, are a change in scoring structure and exercise assessments from Q2 2012, onward. While the change occurred later in the sample period, the publication provided greater structure in the progression of MWDs through the Operational Standards than prior to its release. The structure outlined in Chapter II represents the standards and procedures consistent with the publication and these standards are applied across the entire sample. Where the existence of the Operational Standards remained consistent across the sample, the first five quarters of assessments saw the Basic component scored out of a total of 40 and not 50. While the Obstacle component remained unchanged, the Tactical component saw the Cease Attack exercise duplicated to include a variation of the exercise where the handler was unaware of when the team would be attacked by an intruder and the MWD’s reaction assessed accordingly. Further, the Tactical Crawl exercise was terminated, following release of the publication, and various other scores were altered accordingly. While percentage scores were only specified for Operational Standards 4 and 5 prior to the publication’s release, the updated percentage standards for component totals were applied across the entire sample when determining whether the MWD was deemed “Competent” or not for their respective Operational Standards.

The data was compiled into Excel, in wide format, owing to the ease of use. Unfortunately, this required creating two separate sheets for 2011 and 2012 quarterly assessments as Excel did not have sufficient columns. Accordingly, data for every MWD was entered in every quarter to enable smooth merging in conducting the econometric performance analysis portion of my research.

## B. DATA USED IN ECONOMETRIC PERFORMANCE ANALYSIS

I used the Stata 11 software for the econometric analysis portion of my research. I merged the two sheets of data and then reshaped into long format. From there, I generated dummy variables for gender and whether the dog was sourced from an external vendor or accessed from the RAAF breeding program. In the sample, there were four MWDs that were dropped as they were Dutch Shepherds. Given that these MWDs entered service toward the end of the sample (born October 2011), their absence in estimating the effects of MWD-specific explanatory variables would have negligible impact. This allowed a dummy variable to be generated and control for whether the MWD was of German Shepherd or Belgian Malinois breed.

I also excluded MWDs that were assigned to pool duties, as the empirical evidence produced by Lefebvre et al. (2006) indicates that keeping them in the sample would produce a source of measurement error, owing to not having a relationship with any specific handler. Likewise, I excluded observations that involved retesting to achieve the grade awarded, as this would upwardly bias the estimates when comparing against observations that were not.

Following this restructuring of the sample data, I ran kernel density graphs for each of the variables listed in Table 2. The graphs allowed me to identify any unusual behaviors in how the MWDs may have been scored, specifically when scores were assigned outside of the grading structure. In some cases, closer investigation revealed instances of unit quarterly reports being filled out incorrectly by the assessor/s. I overcame this by generating new variables that produced percentage scores vice numerical. Similarly, I generated percentage scores for all component exercises, for ease of comparison.

Lastly, there were instances during the period of observation that saw some component exercises excluded, owing to some unit-specific reason such as no ammunition or environmental restrictions. By using percentage scores for both component exercises and component totals, I am able to account for these omissions more readily.

### 1. Variation of Observations

Table 2 lists the mean average, standard deviation, minimum and maximum values, and the number of observations "N" for each variable. The variation in number of observations between each of the variables can be attributed to a variety of reasons. Where something such as Unit, Operational Standard, gender or any other variable that is likely to have a binary outcome for the period of observation where the MWD is active, they will exhibit the maximum possible number of observations. However, some component exercises, such as "Tactical: Fire and Movement" or "Tactical: Cease Attack (unknown to handler)" were only introduced following the assessment structure transition, thereby attracting fewer observations. In some cases component exercises were not conducted, owing to some discretionary decision by the unit or resource limitation. An example of this includes, but is not limited to, lack of ammunition for exercises involving gunfire or extreme environmental conditions prohibiting the use of flame for the "Obstacle: Flaming Fire Hoop" exercise.

### 2. Key Variables Explained

Table 2 represents all the variables I maintained within the sample; however, I use only a few of these for econometric analysis. While many of the exercise variables are self-explanatory and are referenced in Chapter II, in the exercise and Operational Standard assessment structure, I will outline some of the more key variables that I will use in Chapter IV.

Table 2. Summary statistics

| VARIABLES | (1) Mean | (2) Std Dev | (3) Min | (4) Max | (5) N |
|---|---|---|---|---|---|
| Male | 0.785 | 0.411 | 0 | 1 | 590 |
| German Shepherd (=1), Belgian Malinois (=0) | 0.495 | 0.500 | 0 | 1 | 590 |
| Age (yrs) | 5.474 | 2.415 | 1.631 | 12.68 | 588 |
| Vendor MWD | 0.351 | 0.478 | 0 | 1 | 590 |
| Male German Shepherd | 0.422 | 0.494 | 0 | 1 | 590 |
| Male, vendor-purchased MWD | 0.263 | 0.440 | 0 | 1 | 590 |
| Vendor-purchased German Shepherd | 0.185 | 0.388 | 0 | 1 | 590 |
| Competent | 0.533 | 0.500 | 0 | 1 | 364 |
| Medical waiver | 0.0909 | 0.288 | 0 | 1 | 528 |
| Basic: Heel score (%) | 0.702 | 0.265 | 0 | 1 | 361 |
| Basic: Distance Control score (%) | 0.910 | 0.234 | 0 | 1 | 363 |
| Basic: Sit and Stay score (%) | 0.862 | 0.282 | 0 | 1 | 363 |
| Basic: Recall exercise score (%) | 0.945 | 0.155 | 0 | 1 | 363 |
| Basic: Down and Stay score (%) | 0.898 | 0.246 | 0 | 1 | 241 |
| Basic total score (%) | 0.863 | 0.131 | 0.300 | 1 | 363 |
| Obstacle: Hurdle score (%) | 0.871 | 0.304 | 0 | 1 | 350 |
| Obstacle: Window score (%) | 0.894 | 0.289 | 0 | 1 | 350 |
| Obstacle: Tunnel score (%) | 0.908 | 0.247 | 0 | 1 | 350 |
| Obstacle: Plank Walk score (%) | 0.893 | 0.274 | 0 | 1 | 349 |
| Obstacle: Stairs score (%) | 0.901 | 0.256 | 0 | 1 | 351 |
| Obstacle: Flaming Fire Hoop score (%) | 0.837 | 0.345 | 0 | 1 | 345 |
| Obstacle total score (%) | 0.884 | 0.180 | 0 | 1 | 351 |
| Tactical: Intruder Detection % score | 0.993 | 0.0668 | 0 | 1 | 364 |
| Tactical: Cease Attack (known to the handler) % score | 0.967 | 0.179 | 0 | 1 | 364 |
| Tactical: Cease Attack (unknown to handler) % score | 0.967 | 0.179 | 0 | 1 | 122 |
| Tactical: Search and Protection % score | 0.948 | 0.114 | 0 | 1 | 363 |
| Tactical: Building Search/Clearance % score | 0.959 | 0.0921 | 0 | 1 | 363 |
| Tactical: Fire and Movement exercise score (%) | 0.829 | 0.313 | 0 | 1 | 100 |
| Tactical: Gunfire Control exercise score (%) | 0.731 | 0.431 | 0 | 1 | 263 |
| Tactical: Tactical Crawl exercise score (%) | 0.416 | 0.418 | 0 | 1 | 211 |
| Tactical: Man-trailing exercise score (%) | 0.789 | 0.307 | 0 | 1 | 363 |
| Tactical: Urban Setting Detection % score | 0.943 | 0.221 | 0 | 1 | 312 |
| Tactical: Test of Courage score (%) | 0.955 | 0.149 | 0 | 1 | 313 |
| Tactical component total score (%) | 0.895 | 0.105 | 0.171 | 1 | 364 |
| Assessed at Operational Standard 1 | 0.0695 | 0.255 | 0 | 1 | 590 |
| Assessed at Operational Standard 2 | 0.0559 | 0.230 | 0 | 1 | 590 |
| Assessed at Operational Standard 3 | 0.0559 | 0.230 | 0 | 1 | 590 |
| Assessed at Operational Standard 4 | 0.819 | 0.386 | 0 | 1 | 590 |
| Unit W | 0.220 | 0.415 | 0 | 1 | 590 |
| Unit X | 0.308 | 0.462 | 0 | 1 | 590 |
| Unit Y | 0.210 | 0.408 | 0 | 1 | 590 |
| Unit Z | 0.261 | 0.440 | 0 | 1 | 590 |

Of the sample MWDs, 78.5% are male, 49.5% of German Shepherd breed and 35.1% sourced from an external vendor vice the RAAF MWD breeding program. Of the MWDs within the sample, 42.2% were male German Shepherds, 26.3% of the vendor purchased MWDs were male and 18.5% of German Shepherd breed.

Given that sex, breed, and accession source are the explanatory variables of interest in my research, the variety of MWDs presents reasonably well given the panel data provides a sufficiently large number of observations.

The mean MWD age within the sample is 5.474 years, with the oldest MWD within the sample being nearly 13 years. Given there are MWDs within the sample who begin service and retire at various ages and times during the period of observation, the spread in age is sufficient for use as a control variable in econometric models.

***Basic component total score (%).*** Given that the number of exercises within the Basic component changed following the grading restructure, a percentage total score was generated for applicability across the entire period of observation. The mean percentage score is 86.3%.

***Obstacle component total score (%).*** While the Obstacle component of the quarterly assessment did not change following the assessment restructure, a percentage score was generated to maintain consistency with the remaining two components. The mean percentage score for the Obstacle component is 88.4%.

***Tactical component total score (%).*** Similar to the Basic component total score, the Tactical component total score was transformed to percentage format owing to the change of grading and the cessation and introduction of exercises upon introduction of the assessment restructure in 2012. The mean percentage score for the Tactical component is 89.5%.

***Competent.*** At each quarterly assessment, MWDs are assessed as either “Competent” or “Not Yet Competent” against their assigned Operational Standard. Across the eight quarterly assessments, 53.3% of the sample was assessed as “Competent” against their respective Operational Standards.

***Units "W," "X," "Y" and "Z."*** I compiled the data from four out of a possible eight RAAF Physical Security units, which have been titled "W," "X," "Y" and "Z." The composition of observations are split across these units as 22%, 30.8%, 21% and 26.1%, respectively.

***Operational Standards 1, 2, 3, and 4.*** Of the 106 MWDs that I recorded across the 24-month observation period, only 1 achieved Operational Standard 5. Accordingly, for the ease of estimation, I recoded this MWD as being at Operational Standard 4. The percentage split of observations across the four standards are 6.95%, 5.59%, 5.59%, and 81.9%, respectively. The high percentage of observations assigned as Operational Standard 4 is intuitive, given all MWDs are trained progressively toward this standard, in order to achieve OLOC.

## C. DATA USED IN MARKOV MODELING FOR FIXED INVENTORY RECRUITMENT FORECASTING

I use the same data set outlined in the sample description of this chapter to build the fixed inventory Markov model in Chapter IV, however collapsed all columns such that only Service Status, Operational Standard, and MWD-specific details were shown. This allowed the data from both 2011 and 2012 to be merged into one Excel sheet and enabled for easier exploration when calculating transition between states.

In compiling the data from the quarterly assessment reports I had generated four states within the Service Status variable: "Pre-service" (prior to arrival at first unit), "Active" (serving as an MWD in regular duties), "Pre-retirement" (identified for retirement), and "Retired" (euthanized or homed with the MWD's handler). The MWDs that were recorded as being of "Pre-retirement" status were unable to render service and subject to unit administrative processes that would see them retired and replaced in due course. As all MWDs within the sample, except for one, were eventually retired following identification, those marked as "Pre-retirement" were relabeled as "Retired." One MWD transitioned from "Pre-retirement" back to "Active" upon transfer to a separate unit, and assigned to pool duties, so was relabeled "Active" across this period.

By collapsing the data down to Operational Standard with five standards and Service Status with three life-cycle stages, I am able to more efficiently summate the transitions between accession, proficiency, and retirement. In Chapter IV, I detail the methodology used in employing the data to generate the transitions, validating them, and applying to a fixed inventory recruitment forecasting model.

# IV. METHODOLOGY AND RESULTS: ECONOMETRIC PERFORMANCE ANALYSIS

## A. METHODOLOGY

The explanatory variables of interest to the RAAF are sex, breed, and source. In considering these as primary MWD-specific characteristics, it is equally, if not more important, to decide which dependent variables to use as measures of performance. I use the binary variable “Competent” as the initial focus of my analysis, as commanders’ primary concerns lie with whether or not MWDs are performing adequately at their respective Operational Standards.

### 1. Dependent Performance Variables

The dependent variable of highest value to RAAF capability planning is “Competent,” which is an indicator for whether an MWD is performing at a satisfactory level and therefore able to deploy into operational environments. However, it is also prudent to break this binary outcome into the three components that are drawn upon in determining whether an MWD is “Competent” or “Not Yet Competent” at their Operational Standard. From here, I run the same model against the three individual component percentage scores: Basic, Obstacle, and Tactical, to ascertain the source of variation in estimating the relationship between the explanatory variables against “Competent.” Given the Basic and Obstacle components are comprised of exercises practiced while at basic training, and the Tactical component introduces new, advanced skills, it is intuitive that the Tactical component presents with the greatest variation. Accordingly, I ran the same regressions against the individual Tactical component exercises.

Finally, I analyze the same explanatory variables against whether an MWD is placed on a medical waiver, not controlling for the type of ailment. Whilst not a performance variable per se, analyzing the relationships of MWD-specific characteristics on propensity to requiring a medical waiver may provide guidance to capability planning and decision making for future canine acquisition. In this respect, highlighting any

potential trends in MWDs requiring medical waivers would allow RAAF to shape their future canine acquisition to optimize longevity.

### 2. Models

I use fixed effects models to control for any unobserved relationships between the fixed independent variables and the selected dependent performance variable. Specifically, I control for the fixed effects of "Unit," with "Unit "W" as the reference group; Operational Standard, with "Operational Standard 1" as the reference group; and Quarterly Assessment, with "Quarter 1 of 2011" as the reference group. In controlling for these fixed effects, I am able to mitigate the degree of correlation between the error term and the dependent performance variable. Further, I also control for age, which would naturally have a relationship with the performance of MWDs in carrying out exercises. Accordingly, my models are as follows:

$$Y_{iust} = \beta_1 \,\text{male}_i + \beta_2 \,\text{German\_Shepherd}_i + \beta_3 \,\text{vendor\_purchased}_i + \gamma \,\text{age}_{ist} + a_u + b_s + c_t + \varepsilon_{iust}$$

where subscript *i* represents individual MWD's observations; subscript *u*, the unit where the MWD is resident; subscript *s*, the Operational Standard at which the MWD is assessed; and subscript *t*, the time at which the quarterly assessment took place over the observation period. Variables *a*, *b*, and *c* represent the fixed effects for unit, Operational Standard, and time of quarterly assessment, respectively. The variable *age* represents the age at which MWDs were assessed, allowing me to control for any relationship it may have with the dependent performance variable. Variables *male, German_Shepherd*, and *vendor_purchased* are all binary variables whose reference groups are female, Belgian Malinois, and RAAF-bred MWDs, respectively. Lastly, *Y* represents the performance-dependent variables Competent (0/1), Basic score (%), Obstacle score (%), Tactical score (%), Medical Waiver (0/1), and all individual Tactical component exercises as detailed in Chapter II.

## B. RESULTS

Table 3 highlights the results of the regression estimations of the model against "Competent," with column (1) including all dogs within the sample that were assessed

against this outcome. As a means to observe the differences between types of MWDs, I rerun the model restricting the sample to male and female dogs, only in columns (2) and (3), with column (4) showing the P-value corresponding to whether the estimates in (2) and (3) are statistically different from each other. I repeat the same structure in columns (5) through (7), with columns (5) and (6) representing vendor-purchased and RAAF-bred dogs, respectively, and column (7) the P-value testing whether the estimates for vendor-purchased dogs are statistically different from RAAF-bred dogs.

Table 3 shows that male and vendor-purchased MWDs produce statistically significant parameters toward being assessed as "Competent," holding all else constant. Specifically, on average male MWDs are 12.7 percentage points more likely than female MWDs, at a 95% confidence level. Furthermore, column (3) shows that, on average, female German Shepherds are 24.2 percentage points less likely than female Belgian Malinois, holding all else constant, however with a standard error of 14.5 percentage points. The estimate for female German Shepherds is statistically different from male German Shepherds, as represented by the P-value in column (4). This significance is not apparent in the estimate for the German Shepherd variable in column (1), as the coefficient represents a weighted average and there are far more male MWDs (284) within the sample than female (79). However, there is very little difference between male German Shepherd and male Belgian Malinois MWDs.

Table 3 also indicates that vendor-purchased MWDs, on average, are 13.4 percentage points more likely than RAAF-bred MWDs to be assessed as "Competent," holding all else constant. The estimates for male and female vendor-purchased MWDs are not statistically different from each other, nor are male vendor-purchased from male RAAF-bred MWDs.

The fixed effects estimates for units, Operational Standards, and quarterly assessments do not exhibit any noteworthy figures. Column 1 indicates that MWDs from Unit Y, on average, will score less than 20.5 percentage points lower than the reference group, Unit W, suggesting MWDs at Unit Y perform more poorly than at Unit W. However, this maybe owing to some other reason, such as stricter grading or adverse climates compared to that of the reference unit.

Table 3. Regression estimates against "Competent"

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* =1 if Competent | | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | 0.127** | - | - | - | 0.089 | 0.146* | 0.622 |
| | (0.062) | - | - | - | (0.105) | (0.080) | - |
| German Shepherd (=1) | -0.033 | -0.007 | -0.242 | 0.0211 | -0.056 | -0.029 | 0.426 |
| | (0.056) | (0.062) | (0.145) | - | (0.113) | (0.067) | - |
| Vendor MWD | 0.134** | 0.093 | 0.210* | 0.462 | - | - | - |
| | (0.057) | (0.064) | (0.117) | - | - | - | - |
| Age (yrs) | -0.019 | -0.010 | -0.004 | - | -0.028 | -0.013 | - |
| | (0.015) | (0.016) | (0.041) | - | (0.028) | (0.023) | - |
| Q2 2011 | -0.147 | -0.144 | -0.169 | - | -0.072 | -0.180 | - |
| | (0.095) | (0.104) | (0.206) | - | (0.160) | (0.119) | - |
| Q3 2011 | -0.075 | 0.003 | -0.446* | - | -0.039 | -0.095 | - |
| | (0.100) | (0.109) | (0.224) | - | (0.172) | (0.124) | - |
| Q4 2011 | 0.028 | -0.008 | 0.003 | - | 0.279 | -0.099 | - |
| | (0.098) | (0.108) | (0.219) | - | (0.170) | (0.122) | - |
| Q1 2012 | -0.030 | -0.016 | -0.174 | - | 0.109 | -0.088 | - |
| | (0.094) | (0.103) | (0.212) | - | (0.166) | (0.116) | - |
| Q2 2012 | -0.120 | -0.237** | 0.095 | - | 0.044 | -0.188 | - |
| | (0.100) | (0.109) | (0.227) | - | (0.175) | (0.123) | - |
| Q3 2012 | 0.197* | 0.164 | 0.230 | - | 0.304* | 0.159 | - |
| | (0.102) | (0.112) | (0.228) | - | (0.180) | (0.126) | - |
| Q4 2012 | 0.182* | 0.124 | 0.369 | - | 0.277 | 0.173 | - |
| | (0.102) | (0.111) | (0.243) | - | (0.173) | (0.130) | - |
| Unit X | -0.084 | -0.148* | 0.326 | - | 0.101 | -0.182** | - |
| | (0.074) | (0.080) | (0.204) | - | (0.161) | (0.089) | - |
| Unit Y | -0.205*** | -0.298*** | 0.261 | - | -0.309 | -0.194** | - |
| | (0.076) | (0.081) | (0.200) | - | (0.203) | (0.093) | - |
| Unit Z | 0.012 | -0.002 | 0.399* | - | 0.075 | -0.041 | - |
| | (0.078) | (0.086) | (0.205) | - | (0.159) | (0.102) | - |
| Assessed at Operational Standard 2 | 0.068 | 0.041 | 0.034 | - | 0.109 | 0.007 | - |
| | (0.134) | (0.152) | (0.262) | - | (0.272) | (0.161) | - |
| Assessed at Operational Standard 3 | -0.181 | -0.261* | -0.125 | - | -0.017 | -0.229 | - |
| | (0.131) | (0.150) | (0.263) | - | (0.241) | (0.162) | - |
| Assessed at Operational Standard 4 | 0.180* | 0.215* | -0.049 | - | 0.278 | 0.119 | - |
| | (0.103) | (0.114) | (0.225) | - | (0.183) | (0.137) | - |
| Constant | 0.446*** | 0.567*** | 0.230 | - | 0.423 | 0.536*** | - |
| | (0.139) | (0.139) | (0.333) | - | (0.291) | (0.173) | - |
| Observations | 363 | 284 | 79 | - | 121 | 242 | - |
| R-squared | 0.143 | 0.172 | 0.393 | - | 0.220 | 0.136 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1

(1) Data compiled from RAAF MWD Quarterly Assessment reports over the period of January 2011 through December 2012, held at HQ 95WG.

(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

(3) Q1 2011 reference group for Quarterly Assessment Fixed Effects.

(4) Unit W reference group for unit Fixed Effects.

(5) Operational Standard 1 reference group for Operational Standard Fixed Effects.

### 1. Basic and Obstacle Components

In order to further explore the variations within Table 3, I break down the model to regress the same explanatory variables against the total component percentage scores for the Basic and Obstacle components (Tables 4 and 5, respectively). The parameters within both tables indicate that nothing of significance is occurring, as far as the relationship between the explanatory variables of interest and the outcome variables are concerned. This is intuitive, as both components involve exercises conducted during basic training at RAAFSFS and with no progression of difficulty or complexity through the Operational Standards.

Table 4. Regression estimates against Basic component score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Basic score (%) | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | 0.020 | - | - | - | 0.008 | 0.021 | 0.641 |
| | (0.017) | - | - | - | (0.028) | (0.021) | - |
| German Shepherd (=1) | 0.002 | 0.007 | -0.008 | 0.646 | -0.021 | 0.014 | 0.0522 |
| | (0.015) | (0.017) | (0.043) | - | (0.031) | (0.017) | - |
| Vendor MWD | 0.016 | 0.010 | 0.024 | 0.345 | - | - | - |
| | (0.015) | (0.017) | (0.034) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 362 | 283 | 79 | - | 120 | 242 | - |
| R-squared | 0.128 | 0.122 | 0.295 | - | 0.250 | 0.142 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1

(1) This model estimates the effect of the explanatory variables on the Basic component total score (%).

(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

Table 5. Regression estimates against Obstacle component score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Obstacle score (%) | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | 0.030 | - | - | - | 0.055 | 0.016 | 0.498 |
| | (0.022) | - | - | - | (0.040) | (0.027) | - |
| German Shepherd (=1) | -0.033* | -0.028 | -0.131*** | 0.0263 | -0.033 | -0.031 | 0.967 |
| | (0.020) | (0.023) | (0.040) | - | (0.043) | (0.023) | - |
| Vendor MWD | -0.021 | -0.020 | -0.043 | 0.492 | - | - | - |
| | (0.020) | (0.024) | (0.033) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 350 | 271 | 79 | - | 116 | 234 | - |
| R-squared | 0.193 | 0.186 | 0.580 | - | 0.328 | 0.150 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1

(1) This model estimates the effect of the explanatory variables on the Obstacle component total score (%).

(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

### 2. Tactical Component

Per the outline in Chapter II, the Tactical component is comprised of exercises that become progressively difficult for MWDs and encompass an array of tasks requiring not just refined olfactory sensing but physical agility, focus, and steadfastness. However, coefficients in Table 6 indicate that nothing of significance across the explanatory variables shows that any gender, breed, or source is statistically different from the reference groups. The estimates do indicate that male German Shepherds, on average, will score 2.4 percentage points higher than females at a 95% confidence level; however, the magnitude is not considered significant enough to warrant consideration in swaying future acquisition decisions.

Table 6. Regression estimates against Tactical component score (%)

| *Outcome* | (1) Tactical score (%) | (2) Male | (3) Female | (4) P-value (2)=(3) | (5) Vendor | (6) RAAF-bred | (7) P-value (5)=(6) |
|---|---|---|---|---|---|---|---|
| Male | 0.014 | - | - | - | 0.032 | 0.007 | 0.516 |
| | (0.014) | - | - | - | (0.020) | (0.018) | - |
| German Shepherd (=1) | 0.022* | 0.024* | -0.004 | 0.0167 | 0.014 | 0.023 | 0.644 |
| | (0.012) | (0.014) | (0.028) | - | (0.022) | (0.015) | - |
| Vendor MWD | 0.024* | 0.021 | 0.040* | 0.598 | - | - | - |
| | (0.012) | (0.014) | (0.023) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 363 | 284 | 79 | - | 121 | 242 | - |
| R-squared | 0.098 | 0.090 | 0.482 | - | 0.162 | 0.106 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Tactical component total score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

### 3. Tactical Exercises

Given the lack of variation in the total Tactical component score, I run the same regression models using the individual Tactical exercise scores to observe any variations amongst the explanatory variables. Tables of all outputs for the individual Tactical exercises are available in the Appendix; however, Tables 7 and 8 show estimates exhibiting the most variation and warrant discussion.

The model within individual Tactical exercises exhibiting the greatest variance is Man-trailing, seen in Table 7. The evidence from columns (1) and (2) in this model indicate that German Shepherds, on average, will score 14.8 percentage points higher than Belgian Malinois MWDs, regardless of gender or source, holding all else constant. This is supported by columns (5) and (6), that show vendor-purchased and RAAF-bred German Shepherds outperform Belgian Malinois MWDs by 10.3 and 14.6 percentage points, respectively. The evidence from columns (5) and (6) also suggests that, on average, vendor-purchased male MWDs will score 11.6 percentage points higher than RAAF-bred males, presenting a significant difference in performance. The parameters

against male and female vendor-purchased MWDs in column (3) suggest that the estimates are statistically different from each other; however, the difference is relatively small, at only 4.5 percentage points. This result is similar with the overall relationship of vendor-purchased MWDs on the total percentage score, being at only 5 percentage points higher than RAAF-bred and with a significantly high standard error.

Table 7. Regression estimates against Tactical: Man-trailing Exercise score (%)

| *Outcome* | (1) Man-trailing (%) | (2) Male | (3) Female | (4) P-value (2)=(3) | (5) Vendor | (6) RAAF-bred | (7) P-value (5)=(6) |
|---|---|---|---|---|---|---|---|
| Male | 0.018 | - | - | - | 0.114* | -0.020 | 0.0890 |
| | (0.038) | - | - | - | (0.061) | (0.051) | - |
| German Shepherd (=1) | 0.148*** | 0.130*** | 0.169** | 0.377 | 0.103 | 0.146*** | 0.887 |
| | (0.034) | (0.039) | (0.081) | - | (0.066) | (0.042) | - |
| Vendor MWD | 0.051 | 0.068* | 0.023 | 0.0776 | - | - | - |
| | (0.035) | (0.040) | (0.066) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 362 | 284 | 78 | - | 121 | 241 | - |
| R-squared | 0.156 | 0.137 | 0.526 | - | 0.221 | 0.170 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Man-trailing score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

The next model worthy of discussion is the Fire and Movement exercise, specifically the performance of vendor-purchased MWDs over RAAF-bred. The evidence in Table 8 suggests that, on average, Belgian Malinois MWDs outperform German Shepherds by 11.3 percentage points, holding all else constant, however with a relatively large standard error. However, despite having a very large standard error, female German Shepherd MWDs outperform Belgian Malinois MWDs by 21.6 percentage points on average, holding all else constant. Vendor-purchased MWDs will score 12.8 percentage points higher than RAAF-bred, holding all else constant. Female vendor-purchased MWDs significantly outperform female RAAF-bred MWDs, at 28.2 percentage points

higher, holding all else constant, however containing a high standard error. Additionally, despite male MWDs not performing at any statistically significant magnitude, RAAF-bred males, on average, score 22 percentage points higher than vendor-purchased males and 21.8 percentage points higher than RAAF-bred females as indicated by columns (5) and (6), holding all else constant. This parameter does contain a relatively high standard error, however the magnitude in difference is significant.

Table 8. Regression estimates against Tactical: Fire and Movement score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Fire & Movement (%) | Male | Female | P-value (2)=(3) | Vendor | RAAF-bred | P-value (5)=(6) |
| Male | 0.110 | - | - | - | -0.002 | 0.218** | 0.137 |
| | (0.077) | - | - | - | (0.152) | (0.094) | - |
| German Shepherd (=1) | -0.113 | -0.012 | 0.216 | 0.0122 | -0.062 | -0.093 | 0.471 |
| | (0.068) | (0.072) | (0.276) | - | (0.184) | (0.074) | - |
| Vendor MWD | 0.128* | 0.063 | 0.282** | 0.115 | - | - | - |
| | (0.067) | (0.070) | (0.127) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 99 | 78 | 21 | - | 31 | 68 | - |
| R-squared | 0.294 | 0.318 | 0.839 | - | 0.195 | 0.430 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Fire & Movement score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

### 4. Medical Waivers

The estimates of my model in Table 9 indicate that, on average, female MWDs are 33 percentage points more likely to be placed on a medical waiver than males, holding all else constant. My results also indicate that German Shepherd MWDs are 16.5 percentage points more likely to require a medical waiver than Belgian Malinois MWDs, holding all else constant. However, the parameter contains a significantly large standard error. Male German Shepherds are, on average, 25.8 percentage points more likely to require a medical waiver than male Belgian Malinois MWDs, holding all else constant.

These parameters are significantly large and carry with them important considerations for the structure of RAAF's MWD workforce, in order to optimize longevity of service.

Table 9. Regression estimates against being placed on a medical waiver

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | =1 if on Med waiver | Male | Female | P-value (2)=(3) | Vendor | RAAF-bred | P-value (5)=(6) |
| Male | -0.333** | - | - | - | -0.263 | -0.219 | 0.288 |
| | (0.133) | - | - | - | (0.203) | (0.172) | - |
| German Shepherd (=1) | 0.165 | 0.258** | -0.017 | 0.0511 | 0.209 | 0.190 | 0.982 |
| | (0.116) | (0.119) | (0.347) | - | (0.196) | (0.135) | - |
| Vendor MWD | 0.008 | -0.082 | 0.579 | 0.265 | - | - | - |
| Average Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | No | No | No | - | No | No | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | No | No | No | - | No | No | - |
| Observations | 78 | 62 | 16 | | 28 | 50 | |
| R-squared | 0.126 | 0.156 | 0.476 | | 0.490 | 0.143 | |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on being placed on a medical waiver.
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

## C. DISCUSSION

### 1. Performance

The evidence in Tables 3 through 8 provide interesting highlights for discussion, as far as the effects of gender, breed, and source on the various performance variables are concerned. From my initial model, I find that male MWDs and vendor-purchased MWDs are approximately 12–13 percentage points more likely to be assessed as "Competent" than females and RAAF-bred MWDs, respectively, holding all else constant. Further, female Belgian Malinois MWDs are higher performing than female German Shepherds. However, overall, there is negligible performance difference between breeds, suggesting interchangeability.

In assessing the same explanatory variables against the Tactical component percentage score, my estimates indicate that nothing about the gender, breed, or source

have any significant impact on the outcome. However, in analyzing the Man-trailing exercise alone, I find that German Shepherd MWDs, regardless of gender or source, perform 15 percentage points higher than Belgian Malinois MWDs, holding all else constant. Of the males in the sample, vendor-purchased MWDs outperform RAAF-bred males, but only by 11 percentage points. Lastly, vendor-purchased MWDs, regardless of gender or breed, outperform RAAF-bred MWDs, but only by 11 percentage points. Against Fire and Movement, I find that vendor-purchased also outperform RAAF-bred MWDs, with vendor-purchased females in particular far outperforming their RAAF-bred counterparts. However, RAAF-bred males far outperform their vendor-purchased counterparts. The results also show that Belgian Malinois outperform German Shepherds, however the high standard errors where breed is concerned lessens their significance, in terms of magnitude.

### 2. Injury

Evidence from my estimates against being placed on a medical waiver suggests that female MWDs are significantly more prone to injury than males. Of the males on medical waivers, German Shepherds are 25 percentage points more likely to require a waiver than Belgian Malinois.

Possible reasons for female MWDs requiring medical waivers more frequently than males maybe include either genetic dispositions or perhaps greater propensity for injury if the female was ever used as part of the RAAF breeding program. In this regard, not controlling for those female MWDs who have ever given birth to a litter may pose as a source of measurement error on the outcome variable.

### 3. Sources of Bias

I would be remiss for providing the results of my models without discussing the potential sources of measurement error or omitted variable bias (OVB) in my estimates. Estimations in regression analyses are seldom without some error or OVB, and the following sections list potential sources in my models.

### *a. Relationship Strength*

Lefebvre et al. (2006) provide empirical evidence that the bond between the handler and their MWD is a significant contributor toward obedience and performance. There is no measure for the strength of the relationship within my data; however, this potential OVB is mitigated by the random assignment of MWD-handler partnerships. Any systemic MWD-handler relationship issues within units, unlikely as it may be, is controlled for by virtue of the use of unit fixed effects. Finally, the RAAF MWD assessment structure is designed to penalize performance where the handler is required to repeat their command, similar to the measures used by Lefebvre et al. (2006).

### *b. Climate*

Climate of unit locations could be listed as a source of OVB, as per the works of Gosling et al. (2010), who suggest that future studies include variables to control for environmental conditions. However, my methodology involved the use of unit and quarterly assessment fixed effects, controlling for any adverse or favorable environmental conditions that may have swayed performance. With season and location controlled, I have mitigated these sources of error.

### *c. Inter-Rater Reliability*

The work of Gosling et al. (2010) identifies inter-rater reliability as a source of measurement error in grading canines prior to entering MWD training. Each of the units within my data is responsible for assessing their MWDs at each quarterly assessment, mitigating such error by the use of unit fixed effects within my models. This does not guarantee that the same graders were used at each assessment throughout the period of observation and that some measurement error may be present within the estimates. However, any measurement error from this source is likely to have a negligible effect on the outcomes, given the high average scores as seen in the summary statistics in Table 2. A recommendation for future analyses would be to construct an experiment involving the use of a team that visits units to conduct quarterly assessments.

### *d.* *Retesting*

While accounting for MWDs that were retested to obtain the score awarded within my data and excluding them prior to running the models, it is possible that MWDs were retested without annotations provided within the quarterly assessment reports. This would result in inflated results and thereby pose a source of measurement error within the estimates. However, if considered a standard practice within some or all units, then my use of fixed effects mitigates such error.

### *e.* *Broods*

As per my discussion pertaining to injury, future analyses may consider controlling for those female MWDs who were part of the breeding program. Through the course of their RAAF careers, some female MWDs are temporarily displaced from their units to return to RAAF Base Amberley and conceive. Should veterinary science indicate that female MWDs are more prone to injury following birth of a litter, then it would prove prudent to control for these MWDs in future estimations.

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# V. METHODOLOGY AND RESULTS: MARKOV MODEL FORECAST

## A. MARKOV MODELING THEORY

Markov modeling is a statistical technique used to aid in manpower planning, to match supplies of human resources with available positions. Manpower planning in this context relies upon the use of aggregates, specifically the numbers within a manpower system flowing into, out of, and between states (Bartholomew & Forbes, 1979). By using flows of numbers into, out of, and within the manpower system, Markov modeling is applied to build probabilities of movement between and within states to create an aggregate picture of the behavior of said system. However, in order for a Markov model to be valid, it must adhere to three conditions as prescribed by Rabiner and Juang (1986):

1. The subject manpower system contains a finite number of states.
2. The Markovian property holds true: the probability of transitioning to some next state is only dependent upon its current state, disregarding its history.
3. The probability of transition between states within the system is stationary, exhibiting little to no variance.

The Markov model process is stochastic and attempts to statistically represent the behavior of a given manpower system by incorporating aggregate numbers, deriving probabilities for transitions between states, and placing into a matrix representing the system. From there, decision makers using Markov models can forecast the behavior of the system by either fixing the distribution of resources within states and varying accessions to understand required resources or, given fixed accessions, understand the resultant manpower system behavior (Bartholomew & Forbes, 1979, p. 56). My thesis constructs a Markov model in the former construct, as I build a forecast requirement for MWD accessions to meet a fixed inventory, determined by the RAAF.

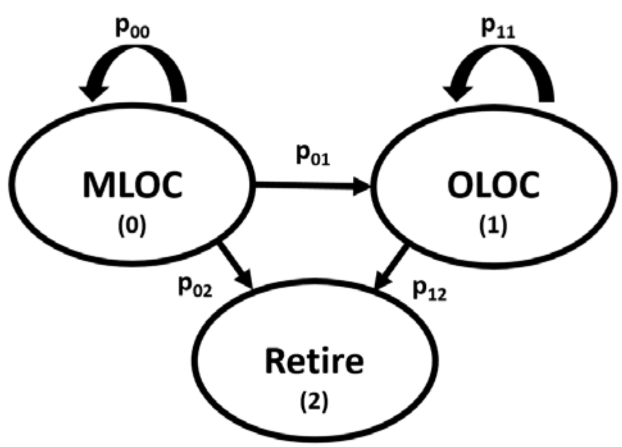
## B. RAAF DOGPOWER SYSTEM

Whereas Markov modeling has thus far been explained in the context of manpower systems, my Markov model applies to the RAAF's *dogpower* system. In this system, I construct the finite states using the data described in Chapter III. Instead of using each Operational Standard as a state within the dogpower system, I categorize into two distinct states: MLOC and OLOC. I simplify into these two categories, as capability planning by RAAF does not require fidelity in understanding where MWDs may lie within MLOC Operational Standards, but rather how many transition to OLOC and total inventory, to meet the physical security demand.

### 1. The Conceptual Model

In breaking down the Operational Standards to the two categories of MLOC and OLOC, I am able to construct a conceptual model with which to build a transition matrix. Figure 2 shows the conceptual model, with "$p_{ij}$" identifying the probability that an MWD will transfer from state "i" to state "j" at the next quarterly assessment.

Figure 2. Conceptual transition model




The conceptual model in Figure 2 shows the transition between MLOC, OLOC, and Retire. Owing to the data only representing a sample of the population of RAAF MWDs, the transition from OLOC to a unit external to the sample cannot be represented

as the transition probabilities would not apply to the population. Accordingly, I assume that the MWDs remain at OLOC whenever transferred out of the sample data.

### 2. Developing a Transition Matrix to Represent the Model

Markov modeling in the context of MWDs builds upon aggregates from flows into, within, and exiting the dogpower system as it would a manpower system. With my data broken down to only the service status and Operational Standard at each quarterly assessment, I develop a matrix representing the numbers of MWDs that enter, transition through, and exit the system. Using these numbers, I derive the transition probabilities between these states as a function of total transitions between quarterly assessments using the equation at Figure 3.

Figure 3. Transition probability derivation

$$\hat{p}_{ij}(t) = \frac{x_{ij}(t)}{\sum x_i(t)}$$

In Figure 3, $\hat{p}_{ij}(t)$ represents the particular probability transition $\hat{p}_{ij}$ between two of the eight quarterly assessments $t$, and $x_i$ represents the number of transitions.

Deriving the transition probabilities, I then construct a transition probability matrix representing the probabilities of transiting between states within the dogpower system:

Figure 4. Transition probability matrix

$$\begin{pmatrix} \hat{p}_{00} & \hat{p}_{01} & \hat{p}_{02} \\ \hat{p}_{10} & \hat{p}_{11} & \hat{p}_{12} \\ \hat{p}_{20} & \hat{p}_{21} & \hat{p}_{22} \end{pmatrix}$$

The result of my method is a transition probability matrix at each quarterly assessment, satisfying the first two principles of Markov modeling. Figure 5 shows an example of one transition matrix derivation between two quarterly assessments.

Figure 5. Transition probability matrix derivation

**FLOWS**

2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired | Total |
|---|---|---|---|---|
| MLOC | 11 | 5 | 0 | 16 |
| OLOC | 0 | 58 | 4 | 62 |
| Retired | 0 | 0 | 0 | 0 |

**TRANSITION PROBABILITIES**

2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | =E118/$G118 | | |
| OLOC | 0.00 | 0.94 | 0.06 |
| Retired | 0.00 | 0.00 | 0.00 |

I then repeat the same technique for each of the transitions within the period of observation, totaling seven transition probability matrices between the eight quarterly assessments. Collectively, I then derive an aggregate transition probability matrix using the total flows into, between, and exiting the various states. The resultant transition probability transition matrix for the RAAF dogpower system is represented in Figure 6.

Figure 6. Aggregate transition probability matrix

**AGGREGATE FLOWS**

| | MLOC | OLOC | Retired | Total |
|---|---|---|---|---|
| MLOC | 75 | 27 | 2 | 104 |
| OLOC | 2 | 426 | 23 | 451 |
| Retired | 0 | 0 | 66 | 66 |

**AGGREGATE TRANSITION PROBABILITIES**

| | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 0.7212 | 0.2596 | 0.0192 |
| OLOC | =E173/$G173 | | |
| Retired | 0.0000 | 0.0000 | 1.0000 |

### 3. Validation

In order to satisfy the third condition of Markov modeling, where the transition probabilities must be stationary, I develop the standard error for each of the seven flows between quarterly assessments. I calculate the standard error using the equation at Figure 7 and then produce the resultant standard errors as seen in Figure 8, for each of the seven transitions.

Figure 7. Standard error equation

$$SE(\hat{p}_{ij}) = \sqrt{\frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{\sum x_i}}$$

Figure 8. Standard error calculation

**FLOWS**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired | Total |
|---|---|---|---|---|
| MLOC | 11 | 5 | 0 | 16 |
| OLOC | 0 | 58 | 4 | 62 |
| Retired | 0 | 0 | 0 | 0 |

**TRANSITION PROBABILITIES**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 0.69 | 0.31 | 0.00 |
| OLOC | 0.00 | 0.94 | 0.06 |
| Retired | 0.00 | 0.00 | 0.00 |

**STANDARD ERROR**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 0.12 | 0.12 | 0.00 |
| =SQRT(K119*(1-K119)/$G119) | | | |
| Retired | SQRT(number) | 0.00 | 0.00 |

This allows me to create an upper and lower confidence level with a 70% interval, or one standard error, for each of the seven quarterly assessment transitions, as per Figure 9.

Figure 9. Deriving upper and lower confidence levels

**TRANSITION PROBABILITIES**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 0.69 | 0.31 | 0.00 |
| OLOC | 0.00 | 0.94 | 0.06 |
| Retired | 0.00 | 0.00 | 0.00 |

**STANDARD ERROR**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 0.12 | 0.12 | 0.00 |
| OLOC | 0.00 | 0.03 | 0.03 |
| Retired | 0.00 | 0.00 | 0.00 |

**LOWER CONFIDENCE LEVEL**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| =J118-O118 | | | 0.00 |
| OLOC | 0.00 | 0.90 | 0.03 |
| Retired | 0.00 | 0.00 | 0.00 |

**TRANSITION PROBABILITIES**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 0.69 | 0.31 | 0.00 |
| OLOC | 0.00 | 0.94 | 0.06 |
| Retired | 0.00 | 0.00 | 0.00 |

**STANDARD ERROR**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 0.12 | 0.12 | 0.00 |
| OLOC | 0.00 | 0.03 | 0.03 |
| Retired | 0.00 | 0.00 | 0.00 |

**UPPER CONFIDENCE LEVEL**
2011: Q1-Q2

| 11_2 | MLOC | OLOC | Retired |
|---|---|---|---|
| =J118+O118 | | | 0.00 |
| OLOC | 0.00 | 0.97 | 0.10 |
| Retired | 0.00 | 0.00 | 0.00 |

Using the confidence interval at each of the transitions between quarterly assessments, I create a test to observe if the aggregate transition probability $\hat{p}_{ij}$ falls within the confidence interval derived in Figure 9 in each transition period. Using the outcome of this test, I aggregate the number of instances where $\hat{p}_{ij}$ falls within each of the seven sets of confidence intervals. In aggregating these instances, I can ascertain if $\hat{p}_{ij}$ is falling within the interval in a normal distribution at a 70% rate (at a minimum) and thereby classify as sufficiently stationary (Sales, 1971, p. 88). Out of a total possible 28 instances

where $\hat{p}_{ij}$ can possibly appear within the confidence interval for transitioning between states as depicted in Figure 2, it appears in 22 instances (see Figure 10). Accordingly, it appears at a 79% rate thereby resulting in a sufficiently stationary $\hat{p}_{ij}$ and satisfying the third condition of Markov modeling.

Figure 10. Instances where $\hat{p}_{ij}$ falls within the confidence interval

| | MLOC | OLOC | Retired |
|---|---|---|---|
| MLOC | 5.00 | 7.00 | 0.00 |
| OLOC | 2.00 | 4.00 | 6.00 |
| Retired | 0.00 | 0.00 | 0.00 |

### 4. Fixed Inventory Model

Having established that my aggregate transition matrix is sufficiently stationary, I use Bartholomew's fixed inventory equation (see Figure 11) to forecast the total number of MWDs in each state.

Figure 11. Bartholomew's equation

$$\mathbf{n}(t) = \mathbf{n}(t-1) \cdot \mathbf{P} + R(t) \cdot \mathbf{r}$$

Source: Sales, P. (1971). The validity of the Markov chain model for a class of the civil service. *Journal of the Royal Statistical Society, 20*(1). Retrieved from http://www.jstor.org/stable/2987007

The variables in Figure 11 are defined as:

1. $\mathbf{n}(t)$: predicted inventory of MWDs at quarterly assessment *t*.
2. $\mathbf{n}(t-1)$: inventory of MWDs at quarterly assessment $t-1$.
3. **P**: aggregate transition probability matrix derived in Figure 6.
4. *R*(*t*): number of MWDs that enter the system at time *t*.
5. **r**: vector matrix distribution *R*(*t*) across states.

In the case of this fixed inventory Markov model, I vary the scalar $R(t)$ in order to meet the predetermined values of $\mathbf{n}(t)$ at quarterly milestones, out to 2023. The vector matrix $\mathbf{r}$ distributes the incoming MWDs as part of scalar $R(t)$ to MLOC only, representing the dogs arriving at their units from RAAFSFS basic training. Given that the transition matrix $\mathbf{P}$ is sufficiently stationary across the 24-month period of observation, I use the inventory of MLOC (36) and OLOC (86) MWDs as at December 2015, provided by RAAF (Buffett, personal communication, 2016) as $\mathbf{n}(t-1)$ to forecast the required $R(t)$ to meet $\mathbf{n}(t)$.

### *a. RAAF MWD Demand*

The total number of MWDs required by the RAAF at end of year 2023 is 204, distributed across MLOC and OLOC in any given manner (Buffett, personal communication, 2016). To meet the incremental increases in physical security demand from beginning 2016 through 2023, acquisition milestones are set by RAAF at Figure 12.

Figure 12. RAAF MWD increase milestones

| 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| 4 | 6 | 5 | 5 | 8 | 17 | 19 | 9 |

Source: T. Buffett, personal communication, 2016.

Unfortunately, given the total number of MLOC and OLOC MWDs at end of year 2015 is 122, the increments in Figure 12 do not summate to the required 204 but to 195. Reading the scheduled milestones, I assume the additional 9 MWDs will be required as part of the 2023 acquisition and forecast $R(t)$ to suit. Accordingly, my revised schedule is as per Table 10.

Table 10. Revised MWD increase schedule

| 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| 4 | 6 | 5 | 5 | 8 | 17 | 19 | 18 |

### *b. Optimization in Excel*

The final step in my methodology is to construct an optimization problem in Excel, whereby I create a mean squared error (MSE) calculating the difference between the actual and required total inventories of MWDs. In following Bartholomew's equation set out in Figure 11, I use the optimization function in Excel to produce an integer solution for $R(t)$ by minimizing the MSE value. I then produce a quarterly schedule for $R(t)$ out to end of year 2023.

## C. RESULTS

The results of my fixed inventory model (Figure 13) show a need for RAAF to acquire a total of 282 MWDs over the eight-year period, assuming a 100% graduation rate from RAAFSFS basic training.

Figure 13. RAAF MWD forecast acquisition schedule

| Year_Qtr | MLOC | OLOC | Total | Required End Strength | Schedule | R(t) | r | |
|---|---|---|---|---|---|---|---|---|
| 2015_4 | 36 | 86 | 122 | - | | | MLOC | OLOC |
| 2016_1 | 32 | 90 | 122 | 122 | - | **5** | 1 | 0 |
| 2016_2 | 29 | 93 | 122 | 122 | - | **5** | 1 | 0 |
| 2016_3 | 26 | 96 | 122 | 122 | - | **5** | 1 | 0 |
| 2016_4 | 29 | 97 | 126 | 126 | 4 | **9** | 1 | 0 |
| 2017_1 | 27 | 99 | 126 | 126 | - | **5** | 1 | 0 |
| 2017_2 | 26 | 100 | 126 | 126 | - | **5** | 1 | 0 |
| 2017_3 | 25 | 101 | 126 | 126 | - | **6** | 1 | 0 |
| 2017_4 | 30 | 102 | 132 | 132 | 6 | **12** | 1 | 0 |
| 2018_1 | 28 | 104 | 132 | 132 | - | **6** | 1 | 0 |
| 2018_2 | 27 | 105 | 132 | 132 | - | **6** | 1 | 0 |
| 2018_3 | 26 | 106 | 132 | 132 | - | **6** | 1 | 0 |
| 2018_4 | 30 | 107 | 137 | 137 | 5 | **11** | 1 | 0 |
| 2019_1 | 28 | 109 | 137 | 137 | - | **6** | 1 | 0 |
| 2019_2 | 27 | 110 | 137 | 137 | - | **6** | 1 | 0 |
| 2019_3 | 26 | 111 | 137 | 137 | - | **6** | 1 | 0 |
| 2019_4 | 31 | 111 | 142 | 142 | 5 | **11** | 1 | 0 |
| 2020_1 | 29 | 113 | 142 | 142 | - | **6** | 1 | 0 |
| 2020_2 | 28 | 114 | 142 | 142 | - | **6** | 1 | 0 |
| 2020_3 | 27 | 115 | 142 | 142 | - | **6** | 1 | 0 |
| 2020_4 | 35 | 115 | 150 | 150 | 8 | **14** | 1 | 0 |
| 2021_1 | 32 | 118 | 150 | 150 | - | **7** | 1 | 0 |
| 2021_2 | 31 | 120 | 150 | 150 | - | **7** | 1 | 0 |
| 2021_3 | 30 | 121 | 150 | 150 | - | **7** | 1 | 0 |
| 2021_4 | 47 | 122 | 168 | 167 | 17 | **25** | 1 | 0 |
| 2022_1 | 42 | 127 | 168 | 167 | - | **7** | 1 | 0 |
| 2022_2 | 38 | 130 | 168 | 167 | - | **7** | 1 | 0 |
| 2022_3 | 35 | 133 | 168 | 167 | - | **7** | 1 | 0 |
| 2022_4 | 51 | 134 | 185 | 186 | 19 | **24** | 1 | 0 |
| 2023_1 | 44 | 140 | 184 | 186 | - | **7** | 1 | 0 |
| 2023_2 | 42 | 143 | 185 | 186 | - | **9** | 1 | 0 |
| 2023_3 | 41 | 146 | 187 | 186 | - | **10** | 1 | 0 |
| 2023_4 | 54 | 148 | 203 | 204 | 18 | **24** | 1 | 0 |

While the results present a forecast for the RAAF in meeting its MWD inventory demands, they are not without limitations. Some of the possible limitations to my forecast follow.

### 1. MWDs Leaving the Sample

I presume that any MWD transferring out of the sample data do so maintaining their OLOC status, when some return to RAAFSFS to conduct re-teaming with new handlers and return to MLOC. This does not affect the resultant $R(t)$ schedule to reach the required total inventory by end of year 2023, as data at the population level would still have them circulating within the RAAF dogpower system. However, my model provides limited fidelity in the resultant distribution of MWDs across MLOC and OLOC, with any desired forecasts down to that level requiring the compilation of the remaining four units of data to model at the population-level.

### 2. RAAFSFS Basic Training

Another presumption I make in forecasting the future acquisition schedule in $R(t)$ is that RAAFSFS basic training, inclusive of the team/re-team process, holds a 100% success rate in graduating MWDTs. The attrition rate and data for the RAAFSFS histories of the MWDs within the sample were not accessed during the data compilation as part of my thesis research. To forecast $R(t)$ more accurately, particularly in the context of MWD acquisition, a future research recommendation would be to access the RAAFSFS basic training data for those MWDs who entered the system during the period of observation and extend the Markov model accordingly.

Ridding my supposition of the 100% RAASFS basic training success rate would mean that my resultant $R(t)$ is representative of the graduation requirement of RAAFSFS, only.

### 3. A Sample, Only

As discussed previously, the sample data is used as a representation of the population of RAAF MWDs and therefore may hold discrepancies against the true behavior of the RAAF-wide dogpower system. While this is true with the use of any sample data, my method in selecting units remains random, thereby mitigating the possibility of deriving biased transition probabilities as a representation of the population. However, the time period of observation may contain inherent discrepancies against the entire time scale of the RAAF maintaining an MWD inventory. Specifically, the stationarity of MWDs retiring may not be truly representative of the actual rate of retirement, thereby leading to a biased forecast.

# VI. CONCLUSION AND RECOMMENDATIONS

## A. SUMMARY

My research has empirically analyzed the performance of RAAF MWDs and forecast the number of canines required, as a means to inform decision makers in structuring their MWD workforce to meet the growing physical security demand. In estimating the effect of MWD-specific characteristics on various performance dependent variables, I have built a picture that shows the effects of gender, breed, and source on performance.

Coupled with the research on sociological and psychological perspectives of MWDs, as covered in Chapter II, my research, analysis, and results provide a balanced picture with which RAAF decision makers can use to inform their physical security capability planning.

### 1. Econometric Analysis

The evidence from my models suggests that male MWDs, purchased from external vendors, are the higher performing MWDs. The initial model of explanatory variables regressed on “Competent” provides evidence consistent with this assertion, as does the evidence from the Tactical exercises exhibiting the greatest variance. While the model for “Competent” does not suggest any statistically significant coefficients for breed, it suggests breeds can be used interchangeably without adverse impacts on the outcome.

The above only applies in the context of “Competent” being the only perception of performance. Suppose performance was measured in terms of the Man-trailing and Fire and Movement exercises. For Man-trailing, the results suggest the RAAF should stick to vendor-purchased German Shepherds, regardless of gender, in order to optimize overall performance. For Fire and Movement, the RAAF should fill its MWD inventory with vendor-purchased Belgian Malinois, however if it must have RAAF-bred MWDs, ensure they are male. If it must have female MWDs, ensure they are vendor-purchased female German Shepherds. Lastly, the results on requiring medical waivers suggest that

RAAF should employ an all-male MWD workforce, if possible. Further, the breed should be predominately Belgian Malinois.

#### *a. Conclusion*

Holistically, there are trends in the results that are very clear: male, vendor-purchased MWDs are the highest performing and significantly less likely to require a medical waiver. Focusing only on being assessed as “Competent,” the two breeds of German Shepherd and Belgian Malinois are interchangeable. However, the exercise-specific models of greatest variance indicate that German Shepherds are higher performing in Man-trailing and Belgian Malinois in Fire and Movement, with all other exercises indicating interchangeability.

#### *b. Recommendation*

The RAAF should look to employ male, vendor-sourced MWDs in order to optimize performance. In breed, the much higher propensity for requiring medical waivers in German Shepherds warrants consideration as to whether the shortfall in performance by Belgian Malinois MWDs in Man-trailing is worth the yield it will gain in MWD workforce longevity and Fire and Movement performance.

Must female MWDs be employed, however, the RAAF should favor German Shepherds for high performance in both Man-trailing and Fire and Movement exercises, but Belgian Malinois for simply being assessed as “Competent,” with either choice being vendor-purchased.

### 2. Fixed Inventory Markov Model

The fixed inventory Markov model produced in Chapter V satisfies the three conditions required for validation. Most importantly, the transition probabilities were found to be sufficiently stationary with 79% of all transitions falling within the derived confidence interval.

#### *a. Conclusion*

The results from the fixed inventory model produced a recruitment schedule detailing the need to source 282 MWDs between 2016 and EOY 2023, to meet the required 204 MWDs distributed across MLOC and OLOC.

#### *b. Recommendation*

In concert with the recommendations from the econometric performance analysis, RAAF physical security capability planners should consider tailoring the acquisition of the 282 MWDs as male and sourced from external vendors, where possible. Further, consideration needs to be afforded as to what is considered optimal performance in deciding between Belgian Malinois and German Shepherd breeds.

## B. RECOMMENDATIONS FOR FURTHER RESEARCH

### 1. Collect RAAF-wide Data

Collecting the remaining four units of data in future research or replication of these results will likely reduce the standard errors in estimating the relationships of the MWD-specific characteristics against the dependent performance variables. In this context, the parameters would cease to be considered estimates but the true, average relationship of the characteristics against the selected dependent variables.

### 2. RAAFSFS Basic Training Performance

The sample data used is constrained to the point at which MWDs commence effective service, not including the time at which they enter RAAFSFS for team/re-team and basic training. Collecting this initial data would provide a sample of the full working cycle of RAAF MWDs, including those that may not have graduated from basic training and track those that returned to RAAFSFS for re-teaming. No information regarding the graduation rates from RAAFSFS were collected as part of my research and would better inform both the econometric analysis and fixed inventory Markov model results.

Further to this, no data was collected on MWDs prior to starting RAAFSFS, which may yield a more holistic picture in comparing the performance of dogs from

vendors and those from the breeding program. Accordingly, the success rate of vendor-sourced canines during their selection process remains unknown and including these within a broader data set may provide more insight.

### 3. Vendor Information

Had the sample data included vendor-specific information, I could have controlled for individual sources and analyzed performance between vendors. Given the results of my research indicate vendor-sourced MWDs as performing higher than RAAF-bred on average, future research may wish to compare MWDs between the individual vendors to ascertain if any significant differences exist.

### 4. Cost Benefit Analysis

Given the strong performance outcomes of vendor-purchased MWDs in this study, the RAAF may wish to consider conducting a cost benefit analysis (CBA) into restructuring its MWD program. While the results of my research point to vendor-purchased MWDs as higher performing compared to RAAF-bred, reviewing the RAAF MWD program with a view to switch to only vendor-sourced canines would come with inherent capability risks. The opportunity cost of losing the corporate knowledge and ability to operate a breeding program would need to be assessed against the performance and manpower gains in switching to a completely outsourced canine supply system. Any such CBA would also need to explore the complete spectrum of canine supply programs, including possible balances between the performance of vendor-purchased MWDs and benefits of retaining an indigenous breeding program.

# APPENDIX. TACTICAL EXERCISE MODEL RESULTS

Table 11. Regression estimates against Tactical: Cease Attack (known) score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Cease Attack (Known) (%) | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | -0.049** | - | - | - | -0.028 | -0.052 | 0.696 |
| | (0.023) | - | - | - | (0.035) | (0.031) | - |
| German Shepherd (=1) | 0.029 | 0.035 | 0.000 | 0.504 | 0.033 | 0.028 | 0.738 |
| | (0.021) | (0.026) | (0.000) | - | (0.038) | (0.026) | - |
| Vendor MWD | 0.019 | 0.025 | 0.000 | 0.636 | - | - | - |
| | (0.021) | (0.027) | (0.000) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 363 | 284 | 79 | - | 121 | 242 | - |
| R-squared | 0.065 | 0.075 | | - | 0.138 | 0.077 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Cease Attack score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

Table 12. Regression estimates against Tactical: Cease Attack (unknown) score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Cease Attack (Unknown) (%) | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | -0.018 | - | - | - | 0.038 | -0.019 | 0.465 |
| | (0.041) | - | - | - | (0.114) | (0.032) | - |
| German Shepherd (=1) | -0.050 | -0.062 | 0.000 | 0.826 | 0.037 | -0.044 | 0.919 |
| | (0.037) | (0.050) | (0.000) | - | (0.125) | (0.027) | - |
| Vendor MWD | -0.058 | -0.076 | 0.000 | 0.450 | - | - | - |
| | (0.038) | (0.049) | (0.000) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 121 | 93 | 28 | - | 41 | 80 | - |
| R-squared | 0.158 | 0.195 | | - | 0.312 | 0.193 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Cease Attack (Unknown) score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

Table 13. Regression estimates against Tactical: Search and Protection score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Search & Protection (%) | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | 0.005 | - | - | - | -0.011 | 0.012 | 0.377 |
| | (0.015) | - | - | - | (0.015) | (0.022) | - |
| German Shepherd (=1) | -0.007 | -0.004 | 0.008 | 0.451 | 0.012 | -0.012 | 0.556 |
| | (0.013) | (0.015) | (0.043) | - | (0.017) | (0.018) | - |
| Vendor MWD | 0.018 | 0.012 | 0.043 | 0.437 | - | - | - |
| | (0.014) | (0.015) | (0.035) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 362 | 283 | 79 | | 121 | 241 | |
| R-squared | 0.061 | 0.069 | 0.171 | | 0.196 | 0.066 | |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Search and Protection score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

Table 14. Regression estimates against Tactical: Gunfire Control score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Gunfire Control (%) | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | 0.058 | - | - | - | 0.043 | 0.056 | 0.915 |
| | (0.052) | - | - | - | (0.093) | (0.064) | - |
| German Shepherd (=1) | 0.020 | 0.047 | -0.113 | 0.684 | -0.181* | 0.070 | 0.105 |
| | (0.045) | (0.047) | (0.170) | - | (0.099) | (0.052) | - |
| Vendor MWD | 0.031 | 0.031 | 0.051 | 0.723 | - | - | - |
| | (0.045) | (0.049) | (0.123) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 262 | 209 | 53 | - | 87 | 175 | - |
| R-squared | 0.485 | 0.520 | 0.505 | - | 0.486 | 0.529 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1

(1) This model estimates the effect of the explanatory variables on the Gunfire Control score (%).

(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

Table 15. Regression estimates against Tactical: Urban Detection score (%)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| *Outcome* | Urban Detection (%) | | | P-value | | | P-value |
| | | Male | Female | (2)=(3) | Vendor | RAAF-bred | (5)=(6) |
| Male | 0.039 | - | - | - | 0.052 | 0.018 | 0.559 |
| | (0.028) | - | - | - | (0.044) | (0.037) | - |
| German Shepherd (=1) | 0.006 | 0.019 | -0.094 | 0.0109 | -0.017 | 0.012 | 0.355 |
| | (0.025) | (0.026) | (0.076) | - | (0.046) | (0.031) | - |
| Vendor MWD | 0.020 | 0.010 | 0.065 | 0.876 | - | - | - |
| | (0.025) | (0.027) | (0.069) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 311 | 245 | 66 | - | 110 | 201 | - |
| R-squared | 0.283 | 0.292 | 0.470 | - | 0.514 | 0.184 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1

(1) This model estimates the effect of the explanatory variables on the Urban Detection score (%).

(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

Table 16. Regression estimates against Tactical: Building Search score (%)

| *Outcome* | (1)<br>Building Search (%) | (2)<br>Male | (3)<br>Female | (4)<br>P-value<br>(2)=(3) | (5)<br>Vendor | (6)<br>RAAF-bred | (7)<br>P-value<br>(5)=(6) |
|---|---|---|---|---|---|---|---|
| Male | 0.004 | - | - | - | 0.003 | 0.008 | 0.424 |
| | (0.012) | - | - | - | (0.026) | (0.012) | - |
| German Shepherd (=1), Belgian Malinois (=0) | 0.004 | 0.006 | -0.009 | 0.237 | 0.012 | 0.008 | 0.317 |
| | (0.011) | (0.012) | (0.028) | - | (0.028) | (0.010) | - |
| Vendor MWD | -0.010 | -0.017 | 0.021 | 0.280 | - | - | - |
| | (0.011) | (0.013) | (0.023) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 362 | 283 | 79 | - | 121 | 241 | - |
| R-squared | 0.102 | 0.099 | 0.249 | - | 0.245 | 0.123 | - |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Building Search score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

Table 17. Regression estimates against Tactical: Test of Courage score (%)

| *Outcome* | (1)<br>Test of Courage (%) | (2)<br>Male | (3)<br>Female | (4)<br>P-value<br>(2)=(3) | (5)<br>Vendor | (6)<br>RAAF-bred | (7)<br>P-value<br>(5)=(6) |
|---|---|---|---|---|---|---|---|
| Male | 0.027 | - | - | - | 0.052 | 0.017 | 0.939 |
| | (0.018) | - | - | - | (0.034) | (0.018) | - |
| German Shepherd (=1) | -0.000 | -0.010 | 0.041 | 0.819 | 0.061* | -0.009 | 0.0726 |
| | (0.016) | (0.015) | (0.065) | - | (0.036) | (0.015) | - |
| Vendor MWD | -0.007 | -0.011 | 0.009 | 0.608 | - | - | - |
| | (0.016) | (0.015) | (0.058) | - | - | - | - |
| Age | Yes | Yes | Yes | - | Yes | Yes | - |
| Quarterly Assessment Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Unit Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Operational Standard Fixed Effects | Yes | Yes | Yes | - | Yes | Yes | - |
| Observations | 312 | 245 | 67 | | 110 | 202 | |
| R-squared | 0.355 | 0.374 | 0.399 | | 0.638 | 0.065 | |

**Notes:** *** p<0.01, ** p<0.05, * p<0.1
(1) This model estimates the effect of the explanatory variables on the Test of Courage score (%).
(2) P-values in far-right column for explanatory variables, only. Robust standard errors in parentheses.

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